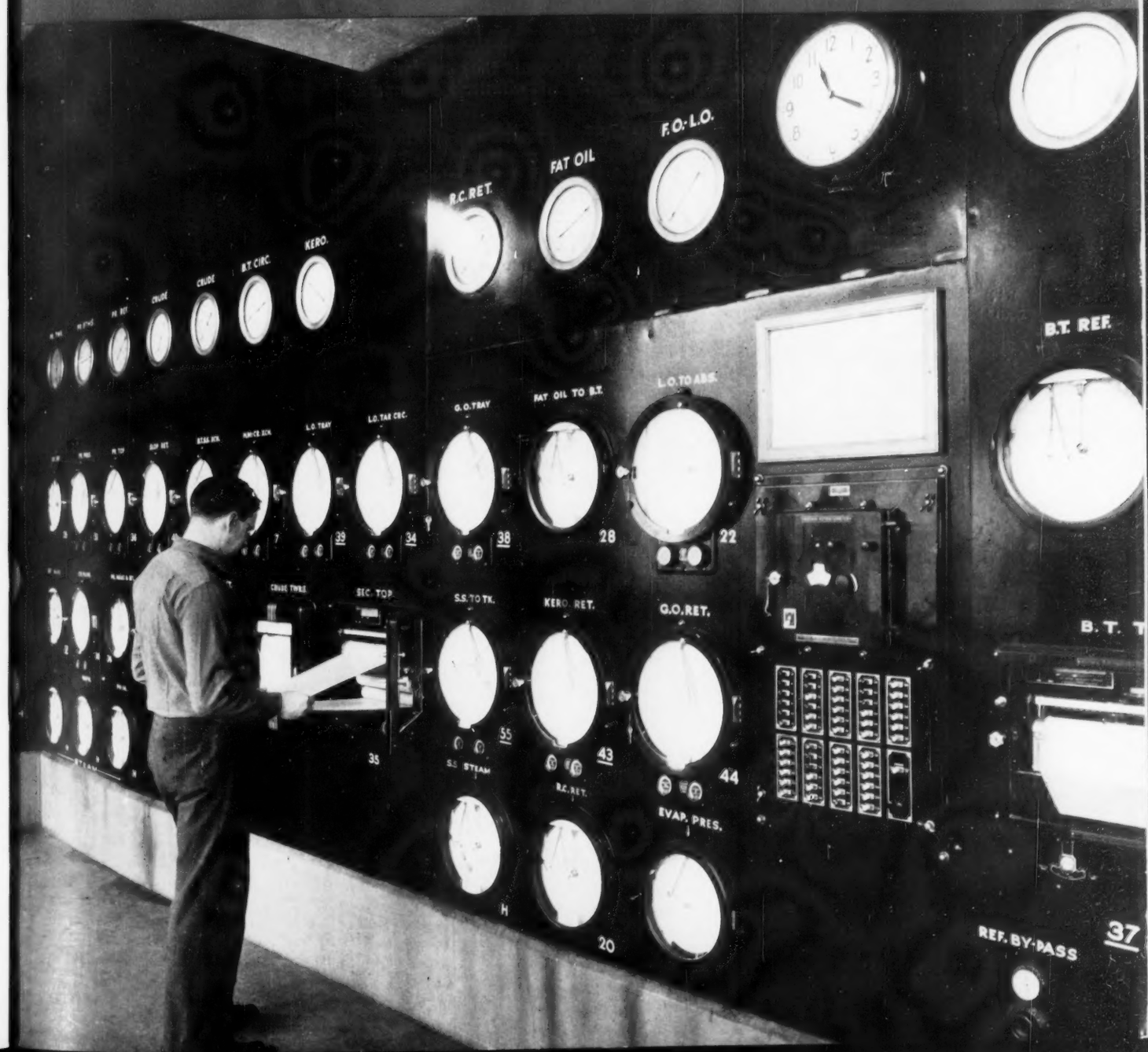
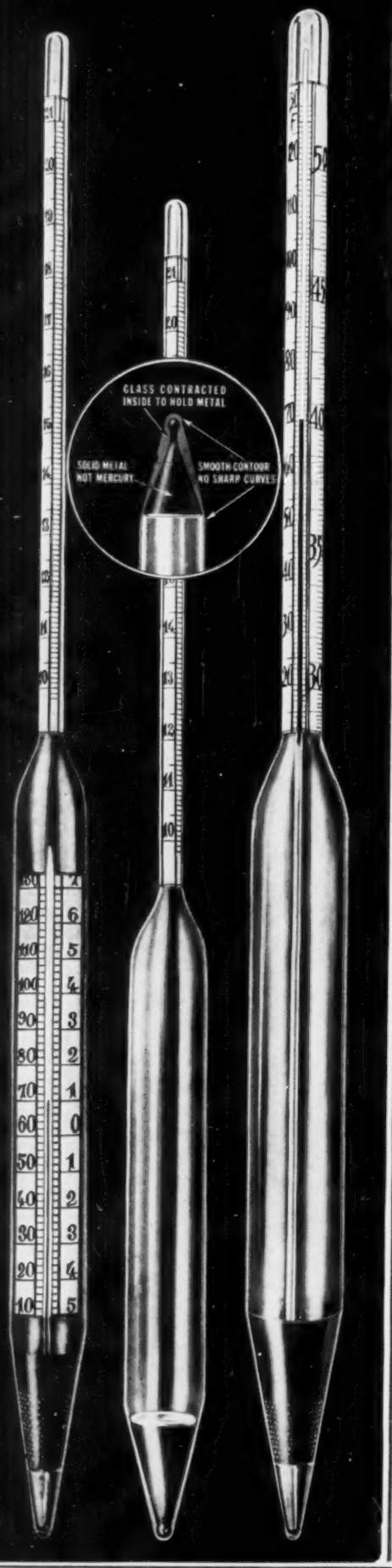
Instruments

THE MAGAZINE OF Measurement and Control

Vol. 11
MAY
1938
No. 5





TAG
HYDROMETERS AND THERMOMETERS

TAG Laboratory Hydrometers and Thermometers are designed to meet the many varied conditions under which temperature and gravity must be measured. Distinctive in appearance, TAG Hydrometers may be easily identified by the striking black design on the back of the thermometer scale of the combined form type, and the attractive silver band in the plain form. TAG Thermometers are marked by sharply engraved numbers and lines—uniformity in dimensions and fine workmanship throughout—also strict adherence to authoritative specifications such as those adopted by the A.S.T.M.

Additional worthwhile and distinctive features of TAG Hydrometers are:

RED INDICATOR. A strip of red glass fused to the stem indicates position of hydrometer scale. An A.S.T.M. requirement.

DOUBLE GRAVITY SCALE. Permits reading from any position when hydrometer rotates. Scales cannot slip because they are fastened with a cement that will withstand a temperature of 300°F.

SOLID BALLAST. No mercury to spill in plain form. No shot can escape in combined form. Metal ballast for high temperatures, withstanding 300°F., is kept in place by enlargement of thermometer stem.

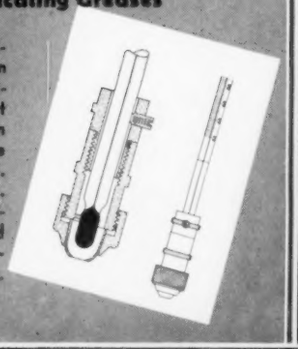
STREAM-LINE TIP. Easy to clean. Sinks quickly into heavy oils. Permits use of extremely sensitive thermometer bulb.

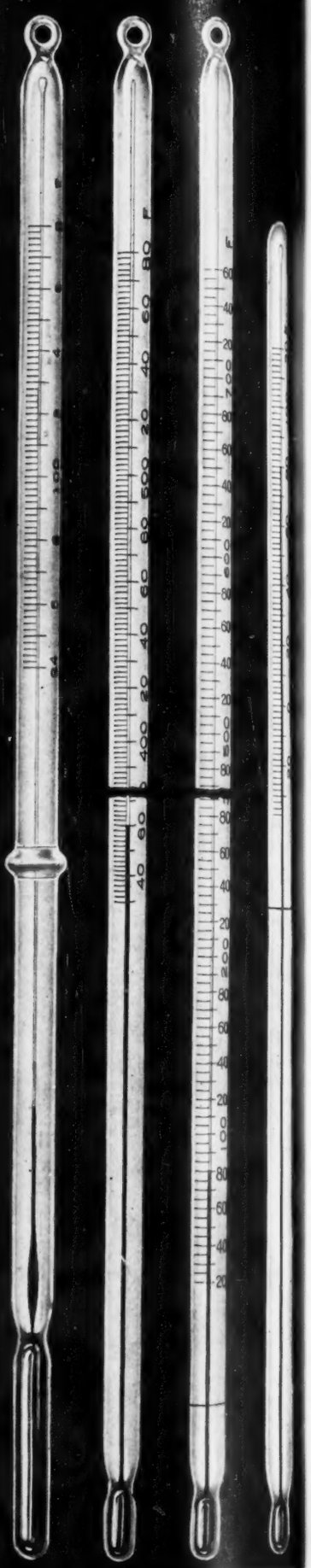
Illustrated here are two of many plates showing TAG Etched Stem Thermometers and Laboratory Hydrometers which appear in the TAG Catalog No. 1100-I. We would like to send you a copy of this latest catalog, for it will prove of valuable assistance to you. In addition to a complete listing of laboratory thermometers and hydrometers, you will find other interesting and instructive information including Fahrenheit, Centigrade and Beaumé Specific Gravity Conversion Tables, as well as useful data relating to the use of these important instruments.

A NEW INSTRUMENT

TAG Dropping Point Apparatus for Lubricating Greases

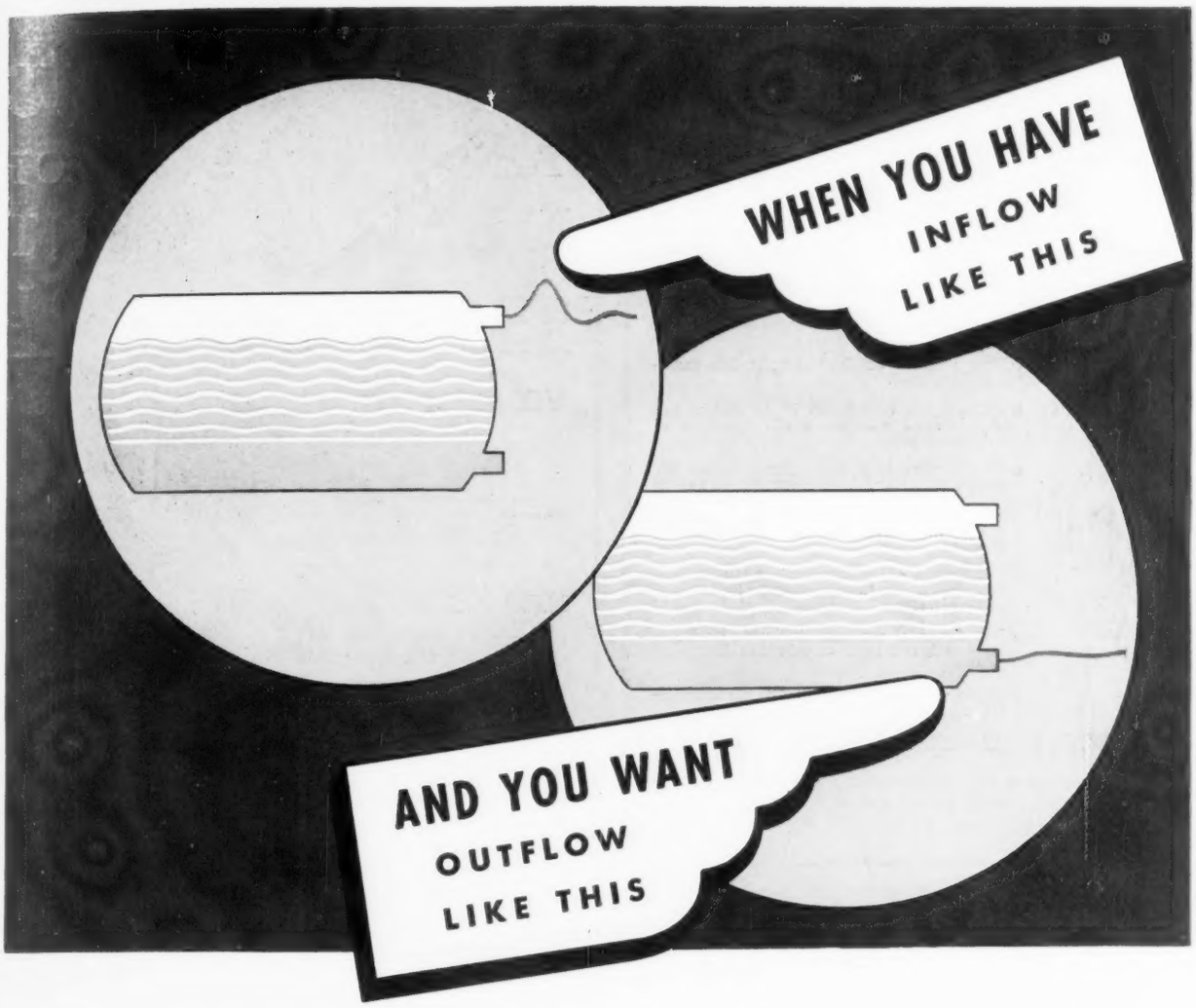
This method is a modification of the well-known and widely used Ubbelohde Dropping Point Method which has been proposed by Committee D-2 of the A. S. T. M. Write for Bulletin No. 1174-I and get the latest information and prices on this new Dropping Point Apparatus.





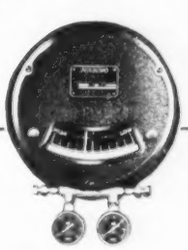
C. J. TAGLIABUE MFG. CO.

Park & Nostrand Ave's., Brooklyn, N. Y.



only FOXBORO can give you true *AVERAGING level control

That it is impossible to secure true averaging control without a very wide throttling range and automatic reset has been proved time and time again. In fact, FOXBORO Model 15 Stabilog Controller can provide 3,000% throttling range—which serves to emphasize the importance of this feature. « « « Results are what count, and FOXBORO's wide experience in the application of averaging type level controls proves conclusively that where true averaging is desired, 100% throttling range is inadequate. « « « If you have problems involving control of level in enclosed systems requiring true averaging control, bear in mind that only FOXBORO can satisfy your requirements. The Foxboro Co., 46 Neponset Avenue, Foxboro, Mass., U. S. A. Branch Offices in 25 Principal Cities.



*True averaging level control is one in which the change of flow is less in percentage than the change of level causing it.

FOXBORO

REG. U. S. PAT. OFF.

STABILOG AVERAGING LEVEL CONTROL

AMINCO ROTAMETERS

Direct-Reading

F & P Liquid and Gas Flowmeters

for measuring accurately the smallest laboratory flows to the largest flows encountered in plant processing.

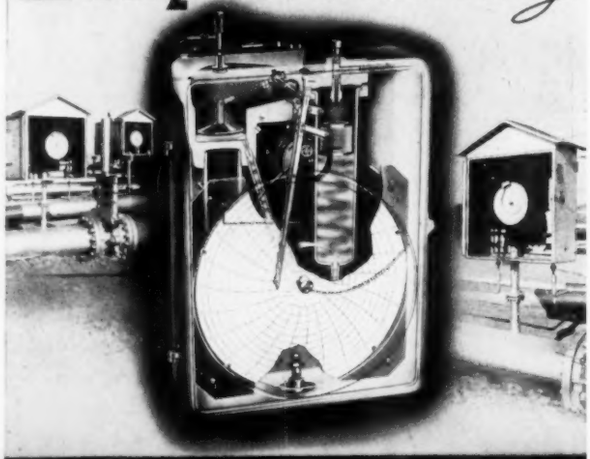
- A fully visible float in an interchangeable precision-bore glass tube indicates rate of flow. Etched capacity scales on the tubes are permanent and read easily.
- Flow readings obtained directly. No metering fluids used.
- Pressure loss (which can be selected to suit requirements) remains fixed regardless of amount of flow.
- Change of capacity range, change from liquid to gas, or change from non-corrosive to corrosive liquids, is made by using a different float which is obtainable at low cost. Floats can be made of materials to resist any chemical.
- Flow graduations spaced uniformly and read easily. No "square root" law involved to distort scales.
- Any degree of accuracy obtainable by changing length and taper of tube and dimensions of float.
- Opened quickly for cleaning or for changing the float without dis-assembling.

Write for Descriptive Bulletin 1065-IN

AMERICAN INSTRUMENT CO.

8010-8020 Georgia Ave. Silver Spring, Md.

X-ray of *Accuracy*



THE WESTCOTT Orifice Meter... the instrument that is meeting a demand of astonishing size and growth throughout the world. Large volume, efficient manufacturing, ingenious design and simplicity ... these alone make the low cost possible.

AMERICAN METER COMPANY

METRIC METAL WORKS *ERIE, PENNSYLVANIA*

Instruments

THE MAGAZINE OF MEASUREMENT and CONTROL

VOL. 11 No. 5

MAY, 1938

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Courtesy Brown Instrument Co.

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INSTRUMENTS The Magazine of MEASUREMENT and CONTROL

M. F. BEHAR
EDITOR

IN THIS ISSUE

The Rouge Plant Power House of the Ford Motor Co. is not only the world's largest industrial power plant but also the largest high-pressure steam generating installation. Not only is the pressure 1250 lbs./in.^{2} and the average temperature 900°F. but the rate is a million pounds of that high-pressure steam *per hour*! Last year we had the rare double privilege of (1) spending a day there and (2) being royally escorted by none other than Power Superintendent Dulmage. Naturally we thought of *you*, dear readers, and the result is the serial beginning in this issue, in which Mr. Dulmage will tell you in detail the important parts played by instrumentation.

Another article on the modern uses of modern instruments in testing motors and their parts. This time R. L. Strode covers the induction type of motor.

Much has been written on the Rockwell method, but it takes Dr. Williams to discuss it thoroughly without "going highbrow" and to explain it plainly without stooping below *your* mental level!

It is years since we printed a letter from a reader. We get many interesting ones but—alas—space limitations . . . you know! However, when two readers, a father (whom we met on our Pacific trip last summer) and his son, write a joint letter, and when the subject-matter is unusual, we have to find space for such a literary collaboration—even though we disagree with the writers' accusation that *Instruments* isn't human enough. Read it and let your editor know what *you* think.

THE FRONT COVER

What! Another petroleum refinery control board? Why not? We don't believe in holding up for several months such a splendid combination of pictorial value and up-to-the-minute engineering as this one of the Sinclair Refining Co.'s installation at East Chicago, Indiana—just received from the Brown Instrument Co.

"THE OLD RELIABLE..."

Experience is a jewel, and it had need to be so, for it is often purchased at an infinite rate.—*Shakespeare*

You take all the experience and judgment of men over fifty out of the world and there wouldn't be enough to run it.—*Henry Ford.*

INTENT as we recently were upon the celebration of *Instruments'* own tenth anniversary, we can—and do—appreciate that this year 1938 is witnessing anniversaries of still greater significance to instrument users—particularly to users of electrical instruments and meters, the manufacture of which by three American firms began half a century ago. These three firms were founded at different times: G-E in 1878, Westinghouse in 1886 and Weston in 1888, but it was in 1888 that Edward Weston began producing his d-c. instruments, Elihu Thomson his d-c. meters and O. B. Shallenberger his a-c. instruments and a-c. meters. These three men have passed on to their reward. The thought comes to our mind that since the deaths of Instruments Publishing Company's President Vigneau in 1936 and of Field Representatives Ripley and Farnham a few months ago, not one official or employee of this company has reached the age of fifty! The majority of our subscribers—judging from the hundred or so whom we have met—are in their thirties and forties. And the majority of electrical instruments and meters which one sees in industrial plants and utilities look as modern as a stratosphere liner. All in all, the field of industrial electrical measurements would seem to be "a young man's game" like aviation or television. It is indeed rich in opportunities for young men, but it possesses a priceless heritage which aviation and television lack: a firm foundation of glorious history and inspiring tradition. Moreover, a happy characteristic of the older electrical measurement engineers—manufacturers and users alike—is their forward-looking attitude. From Otto Knopp on the Pacific Coast to Paul MacGahan on the Atlantic Coast, these lovable veterans are the ones who, when a stripling just out of engineering school says "it can't be done," proceed to do it! No idle boast is the Weston Electrical Instrument Corporation's proud assertion:

> The beginning of a new half-century still finds Weston a typically *young* organization in its attitude toward new industrial wants, new methods for meeting them and new techniques of manufacture.

Perfectly true! And equally true will it be after your editor's impetuous and impish blue pencil has made a slight change in emphasis, thus: " . . . a *typically* young organization."

THE MONTH'S NEW INSTRUMENTS

In this department we strive to report each month ALL the new devices for measurement, inspection, testing, metering and automatic control—in the form of concise technical descriptions.

When writing to manufacturers directly, please mention this department as your source of information.

Or write to Information Section, Instruments Publishing Company.

Air-operated Control Potentiometer

For process-control applications where (1) potentiometer is preferred for measuring system, (2) pneumatic power is preferred for operating valves or dampers and (3) automatic droop-correction or "reset" control principle is required in order to obtain close control despite unfavorable application lag and unsteady demand, new Micromax Pneumatic Control has been developed "as a unit, engineered as a unit," and thus comes ready to install. Noteworthiest feature is provision for selecting a mode of control and adjusting this mode to application lag and demand fluctuations: in some cases, pilot air valve actuated by slide-wire mechanism can have its outlet directly connected to diaphragm of controlled valve; in other cases the user may decide to make full use of four-bellows type pneumatic balance (Fig. 2) which relays

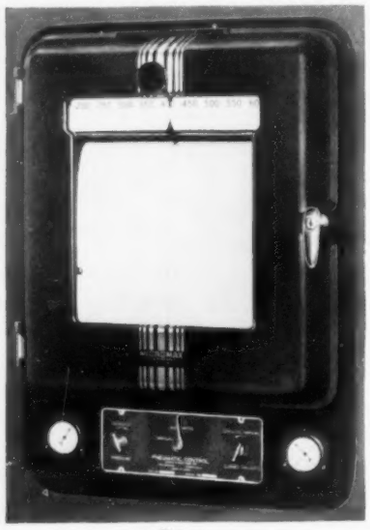


Fig. 1

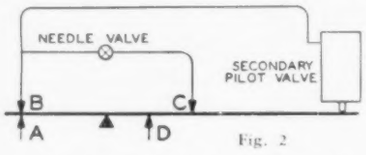


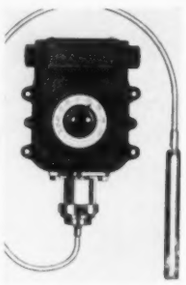
Fig. 2

the primary control action and provides automatic droop-correction (reset). This balance determines the pressure produced by a secondary pilot valve. On the lower side, it is acted upon by forces at bellows A and D. A is loaded by primary-pilot-valve outlet pressure which, when temperature (or other condition) is at control point, is one-half supply pressure. D has one-half the lever arm of A and is loaded by supply pressure, making balance independent of variations in air supply. On upper side, balance is acted upon by forces, having equal lever arms, at B and C. When balance is in equilibrium, each is under secondary-pilot-valve pressure: anything from zero to full supply pressure, permitting control system to be in balance at any position of pneumatic-balance arm—thus providing for controlled valve to assume any position with temperature at control point.

Any change in primary-pilot-valve pressure acts at A to move pneumatic-balance arm, causing a like change in secondary-pilot-valve pressure. This new pressure is transmitted to diaphragm of controlled valve, thus relaying primary control action, causing valve to assume a new position. Change in secondary-pilot-valve pressure is transmitted also to B, offsetting pressure change at A and bringing pneumatic balance to equilibrium, which, however, is only instantaneous. Pressures at B and C start at once to equalize through a needle valve. At C, this produces a pressure change (the amount of which depends on differential between B and C) such as to move arm and valve stem still farther in same direction. Thus, a further change in secondary-pilot-valve pressure is transmitted both to the controlled valve and to B. This supplementary action quickly brings the pneumatic balance to final equilibrium at a new position of its arm—with pressures at B and C equal; with pressure at A again one-half that at D; with the controlled valve at a new position corresponding to the new demand—so that temperature is again at the control point.—*Leeds & Northrup Co., 4955 Stenton Ave., Philadelphia, Pa.*

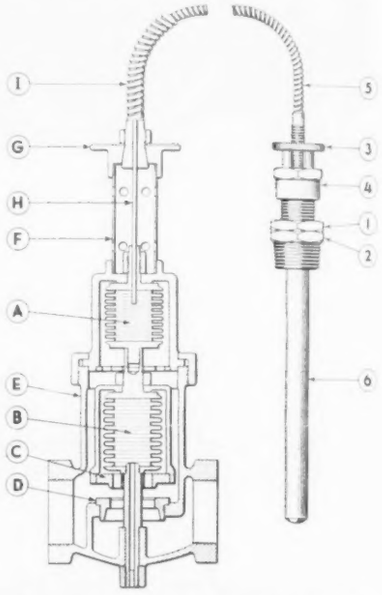
Electric-contact Type Temperature Controls

Functionally similar to maker's previous models, new "Model Z Electric Temperature Control" embodies several refinements and is available in a wide choice of combinations of ranges, switch types, bulb forms, etc. Temperature maximum is 1000°F. or 550°C. Switch element is the "Micro Switch" and may be had normally-closed, normally-open or single-pole double-throw, for two-wire or three-wire control circuits with maximum capacities of 500 or 250 watts a.c. Dial may be supplied uncalibrated (graduated "0" to "50") or calibrated in degrees F. or C. Thermal element is mercury-in-steel type. Maximum tube length is 20 ft. Instrument head is 6" high by 3" deep.—*The Partlow Corp., New Hartford, N. Y.*



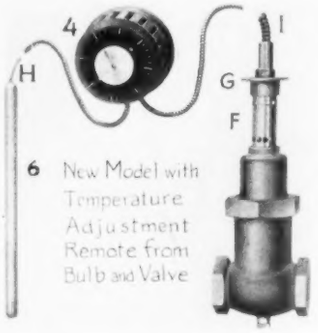
Self-operating Steam-heat Controls

For temperature control of steam-heated applications up to 100-lb. pressure and 275°F., re-designed self-operating temperature controllers are announced in valve sizes from ½" to 1½" and in two models: one with temperature adjustment (4) at bulb, the other with a setting dial which may be located on a convenient panel-board. Power for operation of steam valve is obtained from the heat of the steam itself, through use of "vapo-flash" principle as previously described in great detail (*Instruments*, May 1934, page 97; also Aug. 1936, page 219) whereby a 2° throttling range is obtainable. Single-seated Monel-trim valve provides shut-off sufficiently tight for dead-end service.—*Edison Electrical Controls Div., Thomas A. Edison, Inc., 55 Lakeside Ave., West Orange, N. J.*



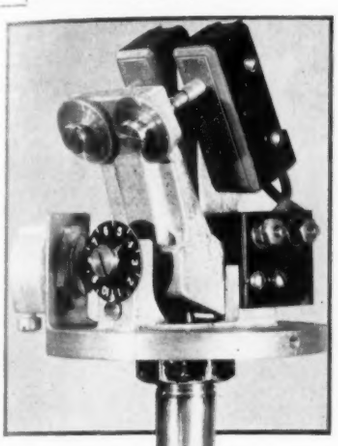
A. Motor bellows; B. Balancing bellows; C. Valve disk; D. Valve seat; E. Bronze body; F. Insulator tube; G. Condenser; H. Capillary tube; I. Flexible armor.

1. Mounting locknut; 2. Union bushing; 3. Adjustment lock; 4. Temperature adjustment; 5. Flexible armor; 6. Bulb.



STEP

3 or 2 FLOATING CONTROL



Obtained Easily

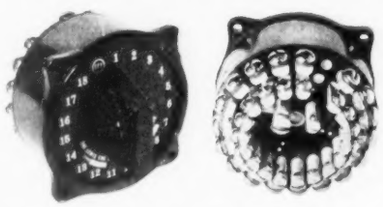
With new two-switch model Burling Temperature Control. Ideal for variable-load applications and for equipment where extremely close control is desired.

Send for particulars

BURLING INSTRUMENT COMPANY

239-241 Springfield Ave., Newark, N. J.

ROTARY SELECTOR SWITCHES *for use with* **THERMOCOUPLES**



There is a "LEWIS ENGINEERED SWITCH" suitable for every multiple thermocouple installation.

Every Switch has an "OFF" position. Every model is designed exclusively for the small voltages generated by thermocouples. Low contact resistance permits very accurate readings. Standard Stock Models.

Part No.	No. of Pos. besides "Off" Pos.	Nominal O.D.	Approx. Wt.
1IS	2, 3, 4	2.5"	7 oz.
10S	6, 9, 12, 18	3.0"	19 oz.
12S	24, 28	4.0"	25 oz.

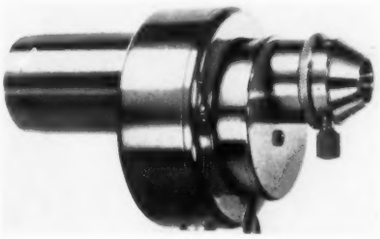
Bulletin IS-37-17 On Request

THE LEWIS ENGINEERING CO.

NAUGATUCK, CONNECTICUT

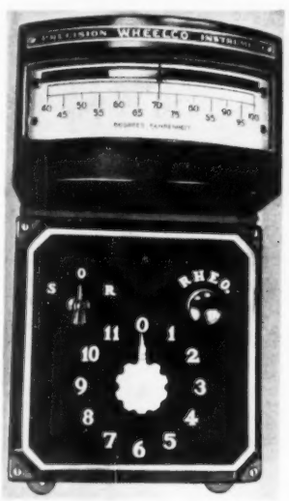
Radiation Pyrometers

Announcement is made of a line of radiation pyrometers, each comprising one of maker's millivoltmeter or potentiometer type indicator or recorder, with an "Ardometer" for the radiant-energy receiver. This type of radiation receiver is essentially a telescope with a thermocouple disk located in focal plane between objective lens and ocular. Observer sights on glowing surface (the temperature of which is to be indicated or recorded) in such manner that he sees a bright zone all around the disk, thereby assuring that disk temperature will bear to source temperature the relation for which the system has been calibrated. Tiny thermocouples soldered to disk thus develop an emf. reproducibly representative of source temperature under standardization conditions. For detailed description of original (German) "Ardometer" see *Instruments*, May 1930, pages 326-327.—*The Bristol Co., Waterbury, Conn.*



Resistance Thermometers

A line of indicating resistance thermometers is announced, specially adapted to the air-conditioning field as well as for industrial applications where it is desired to take regular temperature readings of rooms, air ducts, bulk material in bins, etc. in a temperature range from —30° to +250°F. Several models are available. They may be equipped with multiple switch for connecting up to twenty-one bulbs located at as many different points. All instruments have aluminum cases with black enamel finish.—*Wheelco Instruments Co., 1933 S. Halsted St., Chicago, Ill.*



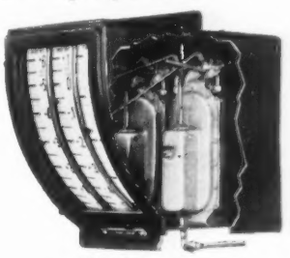
BAILEY METERS

METERS and CONTROL *for Boiler Room Service . . .*

Boiler Meters Indicate, record and integrate Steam Flow from the boiler, record Air Flow supplied for combustion and record Flue Gas Temperature. The use of this meter reduces fuel cost, lessens maintenance and outage, lowers standby costs, and adds capacity.

Bailey Boiler Meter

Multi-Pointer Gages for indicating drafts, pressures, differentials are available with any number of pointers from one to twelve. They are actuated by sturdy yet sensitive diaphragm units.



Multi-Pointer Gage

Flow Meters. For indicating, recording and integrating the flow of steam, feed water, compressed air and other fluids.

Coal Meter

Granular Material Meters For accurately measuring the flow of coal or other granular materials in gravity chutes from overhead bunkers. The total quantity of granular material is shown on a large illuminated counter which may be easily read at a distance of 50 feet.

Control Systems. Make possible the everyday operation of equipment for steam generation and utilization at test efficiencies. They are applied to the control of combustion, feed water, superheat, desuperheat and other factors.

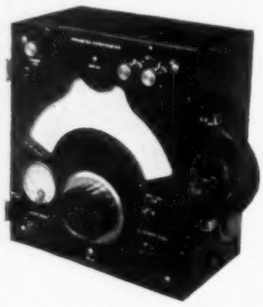
Complete Information on any of the above Bailey products will be gladly furnished upon request. G-7

BAILEY METER COMPANY

1041 Ivanhoe Rd., Cleveland, Ohio

Pocket-size Thermoelectric Pyrometer

New No. 73PO Pyrometer Potentiometer measures 7¾" × 5⅝" × 3¾", weighs 4 lbs. 10 oz., is unaffected by vibration and requires no leveling, hence is recommended not only for general industrial-plant service but especially for various temperature measurements in aircraft, moving vehicles, etc. Eight types of rare-metal and base-metal thermocouples are available. Scale is 8" long, can be calibrated in mv. or for any type of thermocouple, or both temperature and mv. Circuit is of drop-resistor type, requires no standard cell, is fully compensated for temperature effects so that instrument indicates only temperature of measuring junction provided that instrument temperature be between —40°F. and +120°F. Intrinsic accuracy is 1% of scale range. Scales are hand-drawn on white enamel. Small flash-light cells are easily replaced.—*Lewis Engineering Co., Naugatuck, Conn.*



Moisture-proof Selector Switch

New No. 80S rotary selector switch is made in (1) a wall-mounting model (illustrated) with entire front plate removable for attaching leads to thermocouples, etc.; and in (2) panel-mounting model with dial plate raised so that it will be flush and with entire back plate removable. All switches have an "Off" position and from 1 to 28 switch positions. (Carried in stock: 4, 9, 12, 18, 24 and 28; others special.) Brushes are of phosphor-bronze. Action is make and break both conductors of circuit. Connections are in long-and-short pairs for ease in identifying polarity; and binding-posts are stamped with numbers corresponding to switch positions for greater convenience. Dimensions 6" × 6" × 7" deep.—*Lewis Engineering Co., Naugatuck, Conn.*

LIMITROL

Temperature Limit Pyrometer

An automatic, limiting heat Shut-Off device designed to shut off the furnace at any pre-set temperature. Fully automatic — all electrical in operation — no mechanical contacts or working parts —simple in construction. Offers a positive method of preventing over-heating of either furnace or furnace load. Its low original and maintenance cost makes it an economical instrument to own.

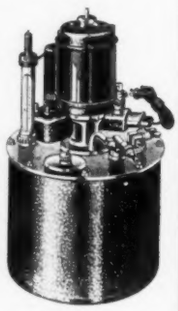
Complete Catalog "G" Sent on Request

PRICE **$87.50**

WHEELCO INSTRUMENTS CO.
1933 SO. HALSTED STREET, CHICAGO, ILL.

Ultra Thermostat

(AFTER HOPPLER)
Temp. Constant ± 0.02° C.
Temp. Range —35° to +250° C.



For
REFRACTOMETRY
VISCOSIMETRY
SEROLOGY

Completely automatic, self-contained. Delivers to the instrument for continuous service 5 liters of constant temperature liquid per minute.

Bulletin HT-254 on request.

JENA KPG ALL GLASS STIRRER
(For Vacuum or Pressure)

Replaces clumsy mercury seal. No supplementary seal or stuffing box needed. Pressure differences as great as 100 mm. of mercury between inside and outside of flask cause no leakage. Also keeps out impurities.

Apparatus, as supplied, consists of bearing and shaft precisely fitted to each other. Inner surface of the bearing tube is accurate within ± 1 to 2 microns.

Leaflet JS 262 on request
Available at leading laboratory supply dealers

FISH-SCHURMAN CORPORATION
250 East 43rd Street New York City

U. S. Agents
Jena Glass Works, Schott & Gen.

Fish-Schurman

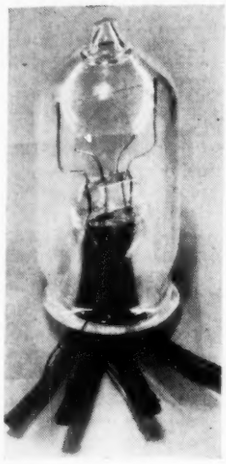
Speed Limit Control Tachometer

Said to meet demand for a simple device that would instantly give warning of overspeeding of diesel or other types of engines, "Reliance Speed Limit Control" tachometer has a pair of contacts installed in a standard tachometer case. Contacts close when a predetermined speed limit is reached. This limit is "set" when the tachometer is assembled and is clearly marked in red on the dial. When engine speed reaches it, contacts close and (1) energize a solenoid or other device to operate mechanism that will hold exhaust valves open or close fuel supply line and thus stop the engine, or (2) operate a light, gong or other warning device without stopping the engine. Where it would be undesirable to shut down the engine, devices can be arranged to command attention of operator first, and then shut down engine if he failed to appear within reasonable time.—*Barbour-Stockwell Co., Cambridge, Mass.*

Hand Tachometer

New idea embodied in latest type Coats Hand Tachometer is that the hand makes two revolutions in each speed range, instead of customary one revolution. It will be seen that the inside scale reads from 25-80 r.p.m. and outside scale continues from 90 to 300. Dial is 3" in diameter and the two full revolutions of the hand thus provide 18" of graduated scale length. Three measuring ranges are available: 25-300, 250-3000 and 2500-30,000 r.p.m., and these are engaged by turning the knurled ring. Eliminating outside thumb-gearshift made it possible to reduce length of tachometer housing. Tachometer is of the cross-pendulum type, resulting in dead-beat indications. —*Coats Machine Tool Company, Inc., 112 West 40th St., New York, N. Y.*

Vacuum . . . Thermocouples



Ranges from 1 milliampere to 10 amperes, in either contact or separate heater types. Prices from $3.00, quantity discounts.

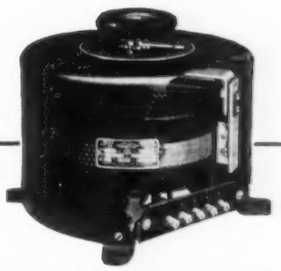
Write for Bulletin "A"

AMERICAN Electrical Sales Co. Inc.
67 E. 8th St. New York, N. Y.

Interval Timer

New "Model A" synchronous-motor-driven timer is designed primarily for installation as an integral part of various electrical appliances and equipment operative on a predetermined time basis, such as processing machinery, etc. Synchronous motor is slow speed, self-start-

ing with enclosed gear train operating in oil. Switch is light acting, quick-make—quick-break mechanism, with silver contacts, totally enclosed. It will operate in any position, is not affected by ordinary vibrations and will cause no radio interference. Rated at 10 amps., 120 volts, a.c., 5 amps., 220 volts, a.c. Normal switch life is said to be one million operations at rated load. Three types of contacts: (1) Normally open; (2) Normally closed; (3) Double throw: One contact is closed during timing intervals opens when indicator returns to zero, instantly followed by the closing of the other contact. Thirteen standard timing scales range from a one-minute dial with divisions in seconds up to an eight-hour dial with 15-minute divisions.—*R. W. Cramer & Co., Inc., 67-69 Irving Place, New York City.*



S-M-O-O-T-H VOLTAGE CONTROL for A.C. circuits

The Type "TH" Transtat is the new continuously variable auto-transformer regulator . . . the ideal voltage control for a.c. circuits. It offers high efficiency, good regulation, great flexibility and dependable construction at moderate cost. Standard types are available for controlling voltage to single-phase and polyphase loads rated 10 Kva. and smaller, 50 or 60 cycles, 115, 230 or 460 volts. May we send you bulletin 51-1 which contains complete data?

TRANSTAT
VOLTAGE REGULATORS

AMERICAN TRANSFORMER CO.
178 Emmet St. Newark, N. J.

To Gauge the Progress of Today's Accelerated Pace . . .

In Industry, Science and Transportation . . . The need for Accurate Timers assumes Greater Importance . . .

GUINAND; GALLET GALCO and SECURITY
Timers set the Standard for Enduring Dependability

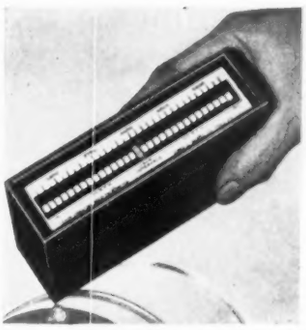
Write for Catalog 7F

JULES RACINE & CO.
20 WEST 47TH ST., NEW YORK

Program Clock and Process Timer

Standard model of this new timer has one large 24-hour dial and a 1-hour dial cam. Two pointers connected with an electrical contact arm ride each dial. Segments are cut in the 24-hour dial at the periods signal is to operate. The 1-hour dial cam has slots at each 15-minute period. At each 15-minute period one pointer drops into a slot on the 1-hour dial, but cannot make a contact until the preset time is reached on both dials. Then both pointers drop at the same moment, resulting in a contact with ringing of the signal for a predetermined period. Four types are offered. In Type P-24 the time periods are set at the factory and signal operates 5 seconds, or as predetermined. Type P-524 is similar except time periods can be set or changed any time. Type P-24A is like P-24 except operating period is adjustable from 1 to 15 seconds; while Type P-524A is similar to P-524, but has adjustable operating period of 1 to 15 seconds. Manufacturer calls attention to flexibility and wide variety of processes or time notification periods: Ninety-six signal periods during each 24 hours made possible.—*Zenith Electric Co., 60-1 South Dearborn St., Chicago, Illinois.*

INSTRUMENTS FOR MEASURING *SPEED*



For many years we have made a specialty of engineers' speed measuring instruments, and today we offer a variety of high grade tachometers and speed indicators, including the vibrating-reed tachometer here illustrated. Descriptive Bulletin 1505-I will be sent on request.

JAMES G. BIDDLE CO.
ELECTRICAL INSTRUMENTS
1211-13 ARCH STREET PHILADELPHIA, PA.

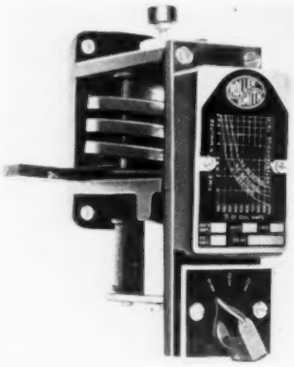
Battery Condition Indicator

Continuously indicating lead-acid storage battery charge without placing any load on the battery to which it is connected, "Chargicator" serves also to in-

dicate safe charging rate and to show when charging is completed. It is a suppressed-zero instrument with an expanded central region of scale. As made for battery users, scale is divided into three sub-scales, each appropriately colored. For testing idle battery, "dead" portion is colored red; low charge portion (L to ½) is yellow; and green (½ to F) represents battery charged. Right-hand region is guide to efficient charging: green shows safe rate; yellow shows battery nearly charged; red warns of destructive overcharging. Ready-to-install outfit includes selector switch and proper number of fused clips, etc., for any given number of batteries.—*Instrument Specialties Co., Little Falls, N. J.*

Thermal-magnetic Trip Device for Breakers

For attachment to maker's Types BD and HD air circuit breakers (see *Instruments*, Dec. 1934, page 267) this new thermal-magnetic trip permits high over-



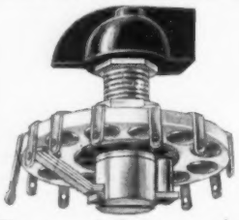
load currents to flow through a-c. machines for safe periods (according to inverse logarithmic relation based on heating rate) but will trip the breaker before a dangerous temperature is reached. Suitable for a-c. circuits in general; particularly recommended for motor circuits to prevent tripping on starting currents.—*Roller-Smith Co., 2132 Woolworth Bldg., New York City.*

WHEELCO Portable Potentiometer

- Specially designed for field and laboratory use.
- Hand drawn millivolt scales, or temperature scales in Fahrenheit, Centigrade, or both.
- Accuracy and sensitivity is far higher than any temperature calibrated pyrometer.
- Made in four different models, having special equipment for different classes of service work.
- Complete data and information furnished on request.

Wheelco Instruments Co.
1933 So. Halsted St. Chicago, Ill.

INSTRUMENT SWITCHES and ACCURATE RESISTORS



SINGLE OR MULTI-DECK

These switches can be supplied with various number of contact points, are compact and rugged with very low contact resistance. Modifications of standard switch can be made to suit various requirements. Switches can be supplied with resistors mounted.

Resistance Range from 1 ohm to 10 megohms

The Shallcross wire wound resistors are used for decade assemblies, accurate to 1/10, 1/2, 1/4, and 1%.

Send for Bulletins 500-HA and 121-HB

SHALLCROSS MFG. CO.
COLLINGDALE, PA.

Portable Potentiometer

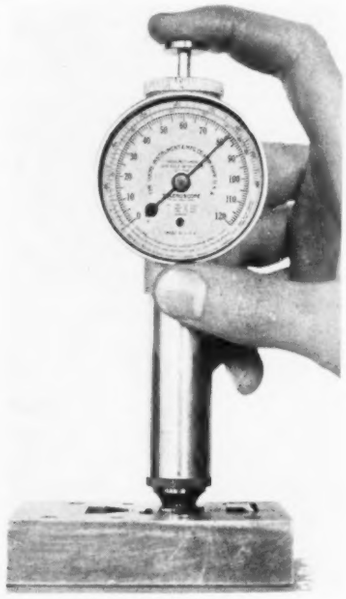
A new portable potentiometer specially designed and built for use in field or laboratory service is available in three different models: "Model 310" with cold

For illustration see maker's advertisement on this page.

junction compensator; "Model 320" with cold junction compensator and run-up box; "Model 330" with cold junction compensator, run-up box, and standard thermocouple line compensating rheostat. When used with thermocouples, this unit becomes a checking instrument, with accuracy and sensitivity said to be far higher than any direct-reading pyrometer. It is standardized with regulation standard cell, and is equipped with precision slide wires and multipliers. Galvanometer is of regulation dual taut-suspension type, complete with lock and zero adjuster. Scales are obtainable calibrated in millivolts or in degrees Fahrenheit or Centigrade, or both. —*Wheelco Instruments Co., 1933 S. Halsted St., Chicago, Ill.*

Tool Makers' Hardness Tester

This new pocket-size indicating hardness tester is fashioned somewhat after the maker's "Model D" dial-indicating Scleroscope, but is so designed that it



can be operated as rapidly as an automatic center-punch. It has the same Shore-Brinell conversion hardness scale as is found on the larger model. A diamond-pointed hammer is used, together with a new improved clutch mechanism. With suitable attachments, tests can be made in a bench vise on a surface plate, as well as free-handed. The instrument proper is 6" long and weighs about 1 lb. In making hardness tests, the instrument is placed on the work and the button on top of the barrel is then pressed down. The pointer automatically indicates the hardness on an enclosed scale.—*The Shore Instrument & Mfg. Co., Inc., 9025 Van Wyck Ave. Jamaica, N. Y.*

Rawson Twin Multimeter

29 ranges in less space than any near equivalent combination—size 12" x 8" x 6"

RANGE OF MEASUREMENTS

D.C. 1 microampere to 1 ampere
20 microvolts to 1000 volts
A.C. (up to 3000 cycles)
2 milliamperes to 3 amperes
60 millivolts to 1000 volts

List Price $165.00

The Rawson measuring instruments are the only ones having two pivot movements whose weight is lifted from jewels when clamped for transit. Electrical clamping does not accomplish this purpose.

Special apparatus built to order

Rawson Electrical Instrument Company

110 POTTER ST. CAMBRIDGE, MASS.
Branch: 91 Seventh Ave., New York City
Representative: E. N. Webber
1313 W. Randolph St., Chicago, Ill.

PORTABLE WHEATSTONE BRIDGE

A high grade instrument for measuring resistances from a fraction of an ohm to 10 megohms. Contains a 4-dial rheostat, ratio dial, galvanometer and battery, all enclosed in a substantial walnut case. Nine coils per dial. Accuracy 1%.

Send for Bulletin No. 105

RUBICON COMPANY

Electrical Instrument Makers

29 North 6th St. Philadelphia, Pa.

Mercury Plunger Switch

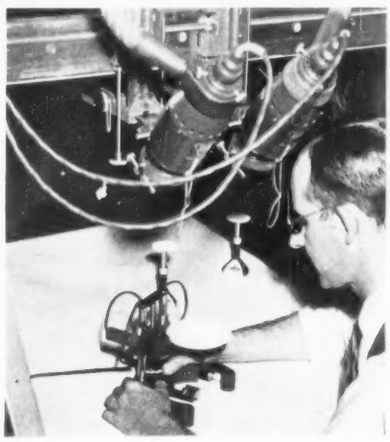
Among uses of this new switch are service as a-c. relay or as across-the-line starter. Operating principle can be understood from illustration: plunger within

For illustration see maker's advertisement on this page.

glass tube is standing ready to be pulled downward when coil is energized. This action displaces mercury in tube and floods contact, closing circuit. When coil is deënergized, plunger again floats on top of mercury. Design is such as to hold arc center shielded by action of plunger around a ceramic cup where make-and-break occurs. Plunger is only moving part. Rating is 30 amps. Dimensions 2½" × 5" × 2¾". Underwriters Laboratories listing has been obtained.—*H-B Electric Co., 2502 N. Broad St., Philadelphia, Pa.*

Two-color Stereoscopic Contour-map Table

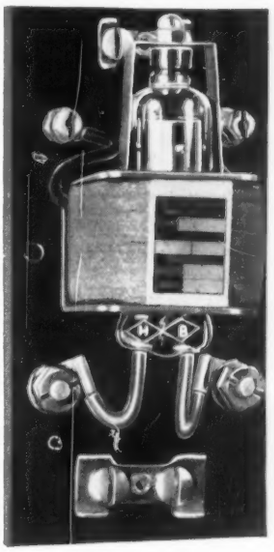
A new stereo-mapping projector has been developed to take full advantage of possibilities of modern automatic cameras shooting at regular intervals



from airplanes. The 7x9" film negatives are reduced on small glass plates and projected down on the drafting table by two adjacent projectors, one red-light, the other blue-light. Projectors are adjusted to produce exactly the same relative positions that the camera occupied when making the corresponding negatives. The mapper, wearing spectacles with one red and one blue lens, then sees on the table before him a single illusory three-dimensional model of the terrain. "The effect is so realistic that he may feel an impulse to prick his finger on a telephone pole." To draw contour map he employs a fixture containing an illuminated pinhole mounted directly above a pencil. This point of light is set at a given height for each contour line. With the new stereo-mapping projector, a month's work by a surveying party is reduced to a few hours' work by an aerial photographer and a mapper.—*Bausch & Lomb Optical Co., Rochester, N. Y.*

You will be interested in this NEW

A-C. RELAY



FEATURES

1. Only one moving part
2. No hum or chatter
3. Mercury to mercury break
4. 30 ampere rating
5. No exposed arc
6. High speed closing and opening
7. Corrosion, dust or dirt cannot stop it
8. Listed under Reexamination Service of the Underwriters' Laboratories, Inc.
9. Easily installed
10. Maintenance free

U. S. and FOREIGN PATS. PEND.

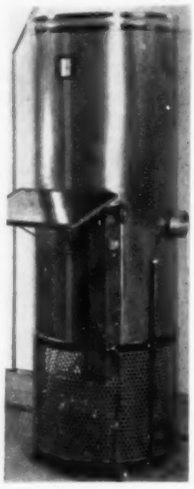
H-B ELECTRIC COMPANY, INC.
MANUFACTURERS OF H-B ELECTRICAL DEVICES

"Clip coupon and attach to letterhead"

H-B Electric Co., Inc.
2502 N. Broad St., Phila., Pa.
Send me Bulletin "A"
Name .....
Company .....
Position .....
Address ..... City .....

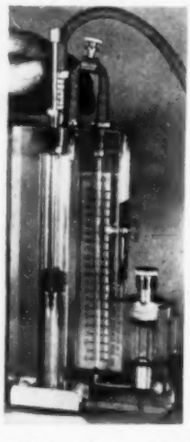
Air Flow Indicator

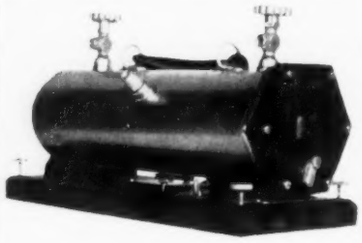
Embodying several refinements which automatically compensate against sources of error previously corrected by computations, "Type VI" represents the most advanced form of the Research Air Flow Indicator, of which the first model was brought out some fifteen years ago. Under the A.S.M.E. classification this new model still belongs to the "area" class, "cone-and-disk" type by virtue of its primary element, but as a whole it would seem to represent a type as yet unclassified, for the cone-and-disk arrangement is supplemented by a pressure-drop compensator comprising a differential manometer and a motor-driven blower. Pulsation-compensating diaphragms in new model have been perfected so that metering errors are eliminated without introducing undesired effects in the air flow to carburetors, etc., when instrument is used in engine studies. True volumetric readings are said to be obtained regardless of variations in atmospheric pressure, temperature or humidity. As with all instruments made by this manufacturer, each is custom-made, in that it is not completed until customer's specifications are received.—*Commercial Engineering Laboratories, 3612 Woodward Ave., Detroit, Mich.*



Pocket CO_2 Analyzer

New Dwyer Pocket CO_2 Indicator is said to be the first that can be safely carried in coat pocket, without sacrificing accuracy and ease of operation. Complete with carrying case and all accessories, it weighs less than 3 lbs. Accurate results are said to be easily obtained in the hands of an inexperienced operator. Tests are made while the indicator is held by hand or in the clip (provided in carrying case). Gas sample is pumped in with a dozen strokes of aspirator bulb while a plunger is held down. Reading is then taken from the mercury column after absorbing unit has been raised and lowered. Body of instrument is made from a new product of the plastics industry said to offer advantages over previous materials. It is clear, colorless, and unaffected by caustic solution. This is not a molded product, but cut from a solid block with all the bores drilled and reamed to size.—*F. W. Dwyer Mfg. Co., 565 W. Washington Blvd., Chicago, Ill.*





AC-ME JUNIOR
SPECIFIC GRAVITY GAS
BALANCE

A Portable Instrument
With Laboratory
Accuracy

Beam with
Float and Indicator Balanced
on Suspension Springs

Provided with External
Locking Device

Catalog No. 22 for
Ac-Me and R.S. Instruments

The Refinery Supply Co.
621 E. 4th St. Tulsa, Okla.

There's a **BECKMAN pH METER**
TO FIT
***your particular* PROBLEM**

The Laboratory Model—for the scientific worker. Combines highest accuracy and versatility . . . Special Electrodes for every research problem . . . Continuous *(non-ballistic)* indication of circuit unbalance.

The Industrial Model (illustrated above)—for Plant and Field use. Combines Operating Simplicity and Ruggedness . . . Continuous *automatic* pH Indication . . . Shielded Glass Electrodes.

Process Control Model—for *Automatic* Process Control. Completely automatic pH Indicator and Recorder for plant installations.

Write for Bulletin N-5
which describes these instruments.

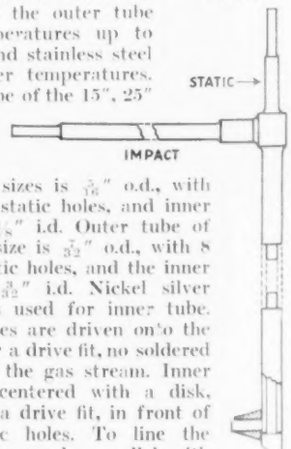
NATIONAL TECHNICAL *Laboratories*

Air and Gas Flow Indicators

For measuring flow-rate of air and gas in order to control gas burning operations, "area" meters of the free-float type are announced in four sizes, with capacities in ft³/hr. as follows: 1-30, 10-350, 20-600, 150-2000. Taper-bore calibrated tube is of Pyrex glass. Each tube is calibrated in conjunction with the float provided with it. Calibration is for 0.60 specific gravity city gas at gage pressure of 4" to 6" water column. Two or more meters may be used to proportion the flow of several gases to a muffle or retort when a mixture of gases is employed for heat-treating or for the processing of materials under specific atmospheric conditions. Construction is such that while inlet must be at bottom, outlet connection may be at either top or bottom. Float is clearly visible when metering any transparent gas: in illustration it is seen below bottom of scale. Indications thus are direct.—*American Gas Furnace Co., Elizabeth, N. J.*

Pitot Tubes

A line of Pitot tubes is announced for air and gas flow measurements (not liquids). Angle type is made in accordance with the A.S.M.E. code. Brass is used for the outer tube for temperatures up to 500°F. and stainless steel for higher temperatures. Outer tube of the 15", 25" and 35" sizes is $\frac{5}{16}$" o.d., with 16 0.02" static holes, and inner tube is $\frac{1}{8}$" i.d. Outer tube of the 12" size is $\frac{3}{32}$" o.d., with 8 0.02" static holes, and the inner tube is $\frac{3}{32}$" i.d. Nickel silver tubing is used for inner tube. Both tubes are driven onto the tip under a drive fit, no soldered joints in the gas stream. Inner tube is centered with a disk, set with a drive fit, in front of the static holes. To line the Pitot tube nozzle parallel with the flow, static connector stem is made parallel with the nozzle and same length as nozzle. Straight-stem type (illustrated) is for use in thick wall ducts in which the angle type cannot be conveniently inserted. Outer tube is $\frac{5}{16}$" o.d., the flow end of which is machined at an angle of 59°, transmitting a true static pressure through the $\frac{1}{8}$" inner tube when faced at right angles to the flow. By means of a conical tip, facing the flow, a true impact pressure is transmitted through the outer tube.—*Ellison Draft Gage Co., 214 W. Kinzie St., Chicago, Ill.*



FOR ACCURATE GAS ANALYSIS . . .

HAYS Portable Combustion Test Sets are in high favor with traveling engineers. The one shown above includes a 3-unit gas analyzer (CO_2, O_2 and CO), a metal armored flue gas thermometer and a Dry Type Draft Gage. Each unit may be used independently of the others. The Hays is known as the "world's fastest Orsat" —complete analysis within 3 to 4 minutes. Extremely accurate, sturdy in construction, compact in size. Many other types available. Send for Catalog 37-253. Write Dept. 11-5-8.

The HAYS CORPORATION
COMBUSTION INSTRUMENTS AND CONTROL
MICHIGAN CITY, INDIANA, U.S.A.

The All Purpose
AIR VELOCITY METER

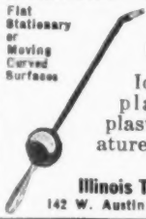
"Alnor" Velometer

Instantaneous Direct Reading

No Timing
No Calculations
Write for Literature

ILLINOIS TESTING LABORATORIES, Inc.
142 W. Austin Ave. Chicago, Illinois

Surface Temperatures



Flat Stationary or Moving Curved Surfaces

The "Alnor" Combination Pyrocon

Ideal for rolls, molds, plates, platens and plastic material temperatures.

Write for bulletin.

Illinois Testing Laboratories, Inc.
142 W. Austin Ave. Chicago, Illinois

NEW "ALNOR" PORTABLE PYROMETER

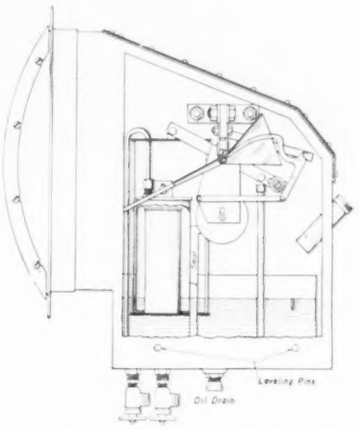
Shock Resisting. Has 5" Mirrored Scale Contained in All Metal Case.

Write for Details

ILLINOIS TESTING LABORATORIES, Inc.
142 W. Austin St., Chicago, Illinois

Air and Gas Flow Indicator

New Air Flow Gage gives volume-rate flow measurements of air and gases across an orifice on a scale with uniform divisions. Square-root movement consists



of a pointer with camtrack in pointer counterweight, and a cam linked to gravity arm of power unit. Pointer is carried on knife-edge fulcrum bearings under fulcrum bearings of power unit. Pointer and track move 50°, 25 above and 25 below horizontal. Power unit consists of a gasometer bell moving within a stationary bell. This differential system eliminates buoyancy loading weight with plus pressure, thereby enhancing sensitivity. A seal prevents oil blowing out of the pan under pressure surges in excess of scale range. The liquid used is a refined petroleum oil of 36 to 39°Bé. Fuel-air-ratio: This gage may be had with two elements for proportioning air and gas flow. Accuracy: With 4" differential pressure, variance is less than 0.06" differential.—*Ellison Draft Gage Co., 214 W. Kinzie St., Chicago, Ill.*

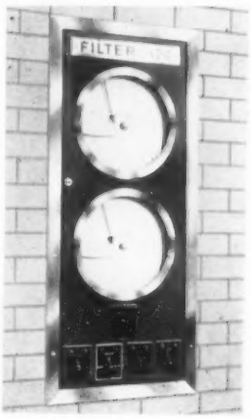
Bending Fatigue Tester

This new machine has been designed for determining endurance properties of paper, cardboard, celluloid, metal foil, wire, etc., under conditions corresponding

For illustration see maker's advertisement on this page.

to the combination of stresses met with in service. Printed matter such as maps, drawings, etc., for example, must be made of papers which resist repeated bending, crimping, folding and pasting. The test is carried out by subjecting the sample, which is hung vertically, to a tension which is 10% of its tensile strength and under this tension it is subjected to a repeated bending 90° to left and right of the vertical at the same section until it breaks. The number of reversals to failure is registered. It is called the fatigue bending number for 10% of the tensile strength. This test can also be made for 25%, 50%, 75% or any other percentage of the tensile strength. Dead-weight tension can be varied from 50 g. to 5 kg. Angle of bend can be varied from 90° down to any desired angle.—*Testing Machines, Inc., 466 West 34th St., New York City.*

CONTROLLING CINCINNATI'S FILTERING COSTS



One of forty filter control panels in the new Cincinnati Water Purification plant. Each contains a Cochrane Flow Rate Recorder and a Cochrane Loss-of-Head Recorder — also switches for electrically operating influent, effluent, wash water and sewer valves.

This is only one instance of the flexibility and adaptability of Cochrane metering equipment. For providing accurate, continuous records of fluid flow which will serve as reliable operating guides, Cochrane Meters are unsurpassed. Their accuracy is so precise that they are *guaranteed* accurate within ½ of 1% of absolute under full load.

Write for Publications #2094 and #2096

COCHRANE CORPORATION
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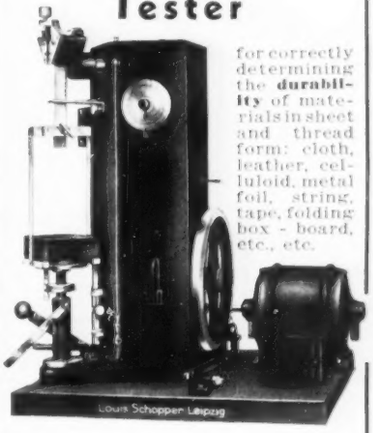
FLOW METERS

SCHOPPER Precision
Bending Fatigue
Tester



for correctly determining the **durability** of materials in sheet and thread form: cloth, leather, celluloid, metal foil, string, tape, folding box - board, etc., etc.

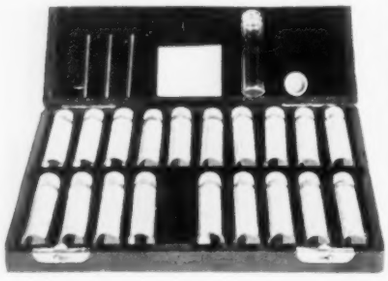
Most materials are subjected not only to abrasion but to repeated stresses. This machine subjects a specimen to **combination tests** according to a technique based on "ideal bending fatigue number."

This is but one of an extensive line of special testing machines representing the new, **correct** techniques. Write for bulletins concerning your problems.

TESTING MACHINES, Inc.
466 W. 34th Street, New York

High-speed Steel Measuring Wires

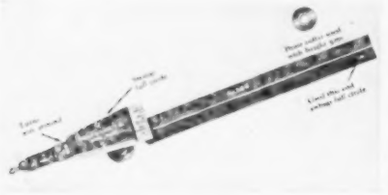
A complete set of measuring wires made of high-speed steel is announced. Known as assortment No. 20HS, it includes "best size" wires which touch at



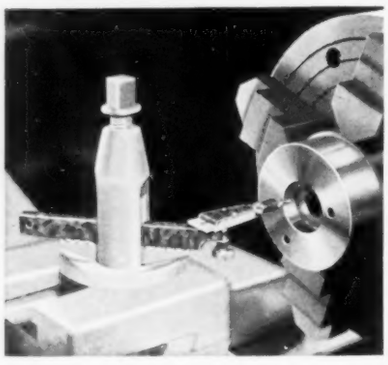
the pitch diameter for pitches: 6, 7, 8, 9, 10, 11, 11½, 12, 13, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32 and 36-pitch. Use of high-speed steel increases life over carbon steel by about 300% and results in a greater average accuracy in the use of the wires. Set is furnished complete in leatherette-covered case.—*The Van Keuren Company, 10 Copeland St., Watertown, Mass.*

Shop Indicator

In new "Universal Junior Indicator No. 564" ball contact is frictionally held and may be set to touch the work at any desired angle. Sleeve which holds contact



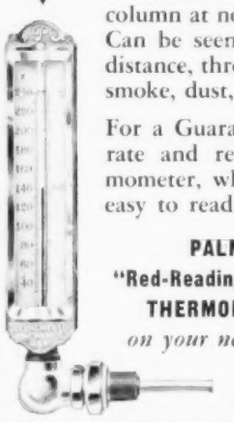
point can be turned completely around. Entire indicator can be swung through a full circle when mounted on the shank. This make it possible to keep graduated scale in most convenient position. Indi-



cator can be mounted on side of one end of shank or on top of the other when used in tool post, or removed from shank and attached to the jaw of a height gage. Reads in thousandths over a range of 0.012". Indicator case is 2½" long; shank is approx. ¼" × ½" × 5".—*L. S. Starrett Co., Athol, Mass.*

EXTRA

IT'S RED!



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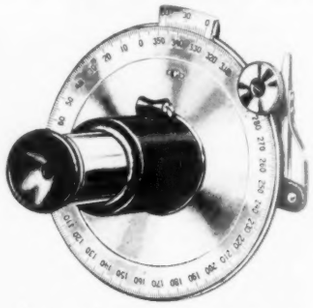
Optical Protractor

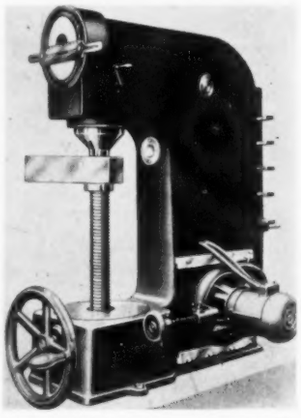
For measuring angles on small objects this new device comprises an eyepiece and a circle of 80mm. (3⅛") diam. divided in degrees and readable to 3 min-



utes by vernier. Circle carries the 90° cross-hairs with which settings are made. Cross-hairs are adjustable so that their intersection may be made to coincide with axis of rotation to any desired degree of accuracy. For fine angular adjustments the circle is rotated by a small pinion. For applications where linear as well as angular measurements are to be made, a scale or filar eyepiece micrometer may be mounted on the protractor.—*Gaertner Scientific Corp., 1211 Wrightwood Ave., Chicago, Ill.*

Motorized Reflex-Brinell Machine

Said to be first motor-driven automatic Brinell testing machine giving results in standard Brinell units, this new tester shows directly and automatically "diameters" of the ball impressions, as required by A.S.T.M. specifications for Brinell hardness testing. It is specially designed and constructed for rapid rou-



tine production testing. Test-cycle, adjustable from 10 to 60 seconds, is such that load is automatically increased to desired maximum, maintained there for a standard period, automatically released to zero. Loading is by weights through single lever system and oil-dash. While load is decreasing, operator has magnified image of the ball impression already available, on ground glass screen, so that no time is lost. Test loads are adjusted by special bolt arrangement, obviating need of handling weight disks. Indenters: Brinell balls of 10, 5, 2½ mm. diam.; Vickers diamond pyramid; Test loads, 120 to 3000 kg; Vertical clearance, about 16".—*Herman A. Holz, 167 E. 33rd St., New York City.*

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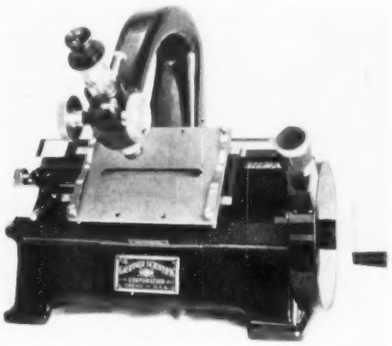
Precision Comparator

Primarily designed for spectrometric work, new Comparator M1201-30B is equally suitable for practically all classes of shop and laboratory measurements



within its range and stage capacity. Range is 100 mm., direct-reading to 1 micron. Throat depth is 150 mm. Therefore, measurements can be made on any point of a 5" × 6" specimen without turning it (and any point on a 10" × 12" specimen by turning it). Thicknesses up to 1" can be accommodated. Magnifications from 5× to 35× are available. Total-length accuracy is 1 micron (1/25400") at room temperature of 22.5° C. (72.5°F.). Lead screw is corrected to eliminate progressive and periodic errors. For rapid alignment of specimen, stage can be moved on an auxiliary slide having a range of 50 mm. Unusual convenience in making observations is said to be afforded by arrangement of drums, scales, magnifier, etc.—*Gaertner Scientific Corp., 1211 Wrightwood Ave., Chicago, Ill.*

Motor Starters

Addition of two new motor starters to maker's line of control devices is announced: "Bulletin 2851" manual across-the-line type motor starter and protective switch has thermal overload protection, with push-button operating feature. A depression in cover of steel enclosure prevents accidental contact. A new mechanism operates silver-to-silver butt type contacts. "Bulletin 4002" a-c. automatic across-the-line type motor starter for non-reversing service provides thermal overload protection, push-button operation and a 3-position selector switch in cover. On "automatic," starter can be operated only from remote control station or pilot device. In "off" position it is inoperative. In "hand" position it operates immediately and stays in running position until switch is turned to "off."—*Ward Leonard Electric Co., Mount Vernon, N. Y.*

Du MONT
Type 168—5 Inch All-Purpose
OSCILLOGRAPH

This modern Cathode Ray Oscillograph incorporates many advanced features. It employs a Du Mont type 54-XH, 5 inch Cathode Ray Tube which provides a hair line trace, uniform focus over the entire screen, long life and high intensity. The features of two stages of amplification on the vertical, separate power supplies for the cathode ray tube and sweep circuit insuring no interaction of controls, a high gain sweep expanding amplifier which allows observation of waves of much higher frequency than the fundamental frequency of the sweep, are only a few of the features which make the type 168 an outstanding instrument.

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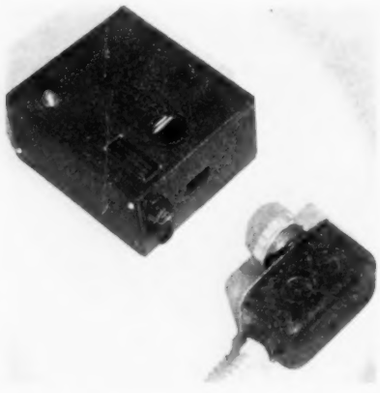
Weather-proof Phototube Relay

Designed and built for outdoor service in all kinds of weather, a new phototube relay unit is announced in which complete protection from rain and snow is

given by the heavy, watertight case and lens visor. A specially designed resistor is mounted in the top of the case, with fins for dissipating heat. The unit is designed for 115-volt d-c. operation.—*G-M Laboratories, 1732 Belmont Ave., Chicago, Ill.*

Photoelectric Control

"Model 50" photoelectric relay complete with light source is a general-purpose control operating on 110-volt 60-cycle supply. Internal telephone type



s-p.d-t. relay carries a load of 2-amp. 110-volt non-inductive. Model 50 requires a minimum of 3 ft.-candles on the photocell. Impulse interval minimum is $\frac{1}{30}$ sec. The control has 1-RCA 6j5 amplifier tube and 1-UCC photocell 1105; the light source is furnished with a 32-cp. automobile type bulb, will operate control at a distance of 25 ft., is supplied with a Bausch & Lomb 2" focal length lens. Four ½" BX knock-outs are provided for wiring and all terminals can be uncovered by removing two screws fastening the bottom plate. The light beam may enter two sides of the box, special knock-outs being provided. Life of vacuum tube averages about 2500 hours, while photocell should operate approximately 10,000 hours.—*United Electronic Industries, 43-47 Rawson St., Long Island City, N. Y.*

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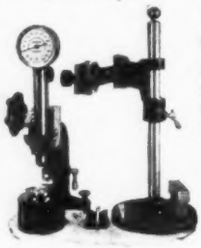

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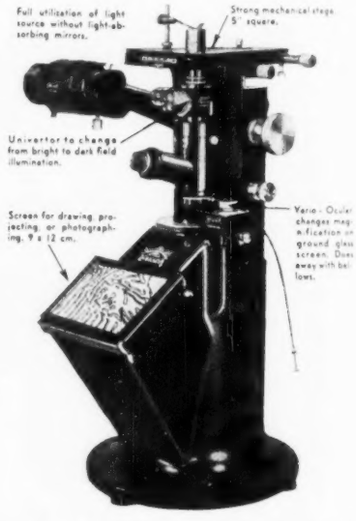
Photoelectric Controls

"Photoswitch" is designation of a new line of photoelectric-relay devices for industrial applications, operating on 110 volt a-c. or d-c. supply, with several light sources to choose from, various types of relays in several ratings up to 100 watts, power relays for higher ratings, and also such devices as counters. Illustration shows "Type A10" designed for high-speed operation (impulse interval minimum $\frac{1}{30}$ sec.) for distances up to 20 ft., which closes controlled circuit when light beam is interrupted. Among other types are "Type A20" for ranges up to 100 ft., and arrangements for remote counters and time totalizers. Rated life of vacuum tube is 1000 hours. Current consumption of Photoswitch proper is 30 watts.—*Photoswitch Inc., 21 Chestnut St., Cambridge, Mass.*

Universal Microscope

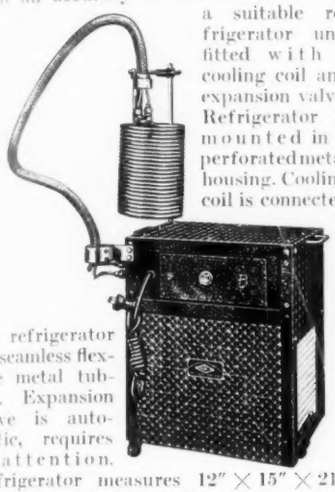
Of radically new design, and said to be more nearly universal than any other optical equipment, the "Metaphot" permits the following classes of work: (1)


Full utilization of light source without light-absorbing mirrors.
Strong mechanical stage 5" square.
Univertor to change from bright to dark field illumination.
Screen for drawing, projecting, or photographing, 9 x 12 cm.
Vario-Ocular changes magnification on ground glass screen. Does away with bellows.

visual examination, (2) photography, (3) projection, (4) tracing and (5) demonstration—in connection with following methods of illumination: (1) transmitted light in bright-field or dark-field, (2) incident light in b-f. or d-f., (3) unilateral incident light, (4) polarized incident light, (5) fluorescent light. All units are mounted on one cast-iron base which even includes the bellowless camera, so arranged that monocular observation in eyepiece or observation on screen are both equally convenient for operator, who sits in natural posture for any class of work. Change in magnification is obtained without bellows through a patented vario-ocular. Objectives and eyepieces of any make can be interchanged. Choice of 130-mm. concentric rotating stage or 120-mm. mechanical stage with verniers.—*George Scherr Co., 120 Lafayette St., New York City.*

Portable Cooling Unit for Baths and Tanks

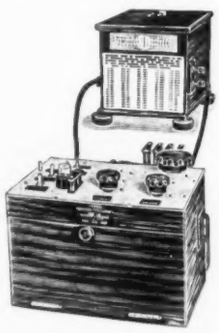
A portable cooling unit for use in baths or tanks where bath temperature is to be maintained at or below room temperature with an accuracy of ±1°C. consists of a suitable refrigerator unit fitted with a cooling coil and expansion valve. Refrigerator is mounted in a perforated metal housing. Cooling coil is connected



to refrigerator by seamless flexible metal tubing. Expansion valve is automatic, requires no attention. Refrigerator measures 12" × 15" × 21" high, is mounted on ball-bearing casters, requires no installation: roll cooling unit to bath or tank, immerse coil in bath liquid, set thermoregulator and place it in bath, plug in to the current supply, and unit is ready for continuous duty. "No pipe connections to be made; no valves to operate; no adjustments to be made other than setting the thermoregulator; no boring of holes or breaking of pressure connections; no brine or water cooling system required."—*American Instrument Co., 8027 Georgia Ave., Silver Springs, Md.*

Photoelectric Colorimeter

Said to bring to colorimetric methods the accuracy heretofore associated only with slower gravimetric techniques, the Evelyn Photoelectric Colorimeter is a



single-cell direct-reading photoelectric photometer for increasing the accuracy, speed, and objectivity of colorimetric chemical analysis. Among features listed by maker are: (1) Availability, for use with the equipment, of an exceptionally complete series of stable light filters covering entire range of visible spectrum; (2) Permanency of light filter characteristics due to their all-glass composition; (3) Unusual stability of light intensity; (4) Utilization of convenient and inexpensive test-tube type of absorption cells (5) Standardization of the apparatus to facilitate widespread adoption, by users of the equipment, of constants determined by a central laboratory when such constants cannot be conveniently determined by individual workers due to the rarity of the pure substance involved, or to other cause.—*Rubicon Co., 29 N. Sixth St., Philadelphia, Pa*

Voltage Regulators

Three new series of voltage regulators are announced in cased (illustrated) or uncased models, each in six ratings from 25 to 1000 watts: (1) input 95-130 volts 60-cycle, output 115±1%; (2) input 95-130 volts 50-cycle, output 115±1%; (3) input 190-260 volts 50-cycle, output 230 ±1%; all single-phase, all for unity power factor load. Also 1500- and 2000-watt units on special order. Principle employed is combination of two transformers with primaries in series, one operating at high magnetic density and partly resonated by means of a capacitor; secondaries connected in series opposed. Changes in load alter output voltage to new stabilized values (this maximum effect being 3% in lower rat-

ings and 1% in higher ratings) but for any given load from zero to full-rating the output voltage will be held to ±1% regardless of input voltage fluctuations within operating ranges given above.—*Raytheon Mfg. Co., 142 Willow St., Waltham, Mass.*

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AIR-FLOW METERS
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WATTHOUR METERS
KELVIN BRIDGES
D-C VOLTMETERS
CATHODE RAY OSCILLOGRAPH
A-C WATTMETERS
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A LIST of the instruments in use at ETL reads like the catalogues of a score of manufacturers. It covers the fields of electricity, chemistry, metallurgy, illumination, strength of materials, power and many others.

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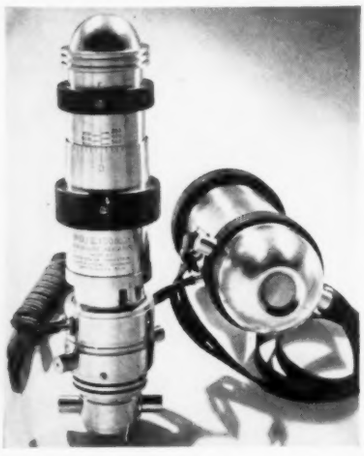
Direct-reading Scale Fractional-inch Gage

"Ames Dial Scale No. 21" is a decidedly new form of calipering device, measuring directly (see black arrow) in 64ths, 32nds, 16ths, 8ths and larger fractions to

its one-inch capacity. Moving thumb or finger forward or backward against operating wheel (white arrow) causes spindle and upper anvil to raise and lower and the dial to turn. Measurement of part placed between anvils then appears in dial slot.—*B. C. Ames Co., Waltham, Mass.*

Pressure Indicator

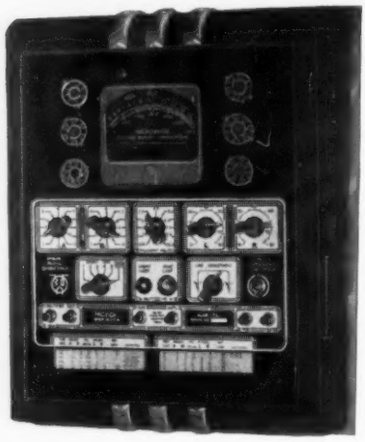
Developed for measuring peak pressure in internal combustion engines, etc., in which successive pressure cycles are of the same form, "Premax" indicator is



said to "constitute a radical improvement over any previous type." It has been approved by the U. S. Navy. A simple adjustment, automatically correcting the readings for inertia of moving parts, renders the indicator capable of accurately measuring compression and combustion pressures at any engine speed and any rate of pressure rise. Essential parts are a piston exposed to the engine pressure, a helical adjustable-tension spring against which the piston acts, and a neon-light circuit with a contact switch operated by the piston. Water-cooling keeps indicator cool during long periods of operation. Maximum stress of spring at top scale reading is well below safe working stress of the spring material, so that spring can be used continuously in upper region of scale without danger of set or fatigue. Neon light flasher provides means of observing any movement of piston at high engine speeds, thus eliminating human element in making observations. Flasher, of compact size, can be conveniently held in the hand or suspended by shoulder strap. For making a measurement, observer rotates vulcanite ring nut located below scales until cessation of neon-light flicker indicates that spring tension just balances the maximum cylinder pressure—which is then read off the scales. Standard model reads up to 1200 lbs./in.^{2}.—*Bacharach Industrial Instrument Co., 7000 Bennett St., Pittsburgh, Pa.*

Tube Tester

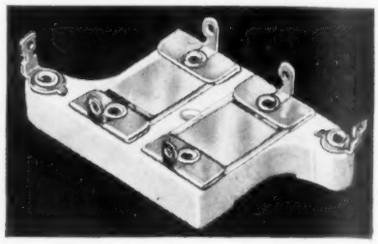
New Models T-53-P and T-53-C dynamic mutual conductance tube testers, with illuminated-dial instruments, indi-



cate both d.m.c. in microhoms and "Good, Bad and Doubtful." Among features are: only one setting to make; sufficient plate current to check both emission and mutual conductance; check gas content; detect both short and open elements and open suppressor grid; short tests made hot or cold; unit not affected by amount of plate current. Available in counter type (illustrated) and portable type.—*The Hickok Electrical Instrument Co., 10514 DuPont Ave., Cleveland, Ohio.*

Production Capacitors

Said to be an entirely new type, "Silver Cap Condenser" maintains capacity value within tolerances said to be heretofore unheard of in regular production components. It is based on the use of conducting films of silver, chemically deposited on thin sheets of India ruby mica. Adjustment of capacitance is accomplished by removing required amount



of silver. Stability: "On being subjected to 90% humidity at 100°F. for 24 hours, the Q was measured at over 3000; on heat runs, the change in capacity was less than 0.1% with 90°F. rise in temperature."—*F. W. Sickles Co., Springfield, Mass.*

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Ford Power Plant Instrumentation

In Five Articles, Specially Written for *Instruments*

1—Boiler Room Instrumentation

By W. W. DULMAGE
Power Department, Ford Motor Co.
Dearborn, Michigan

INTRODUCTION

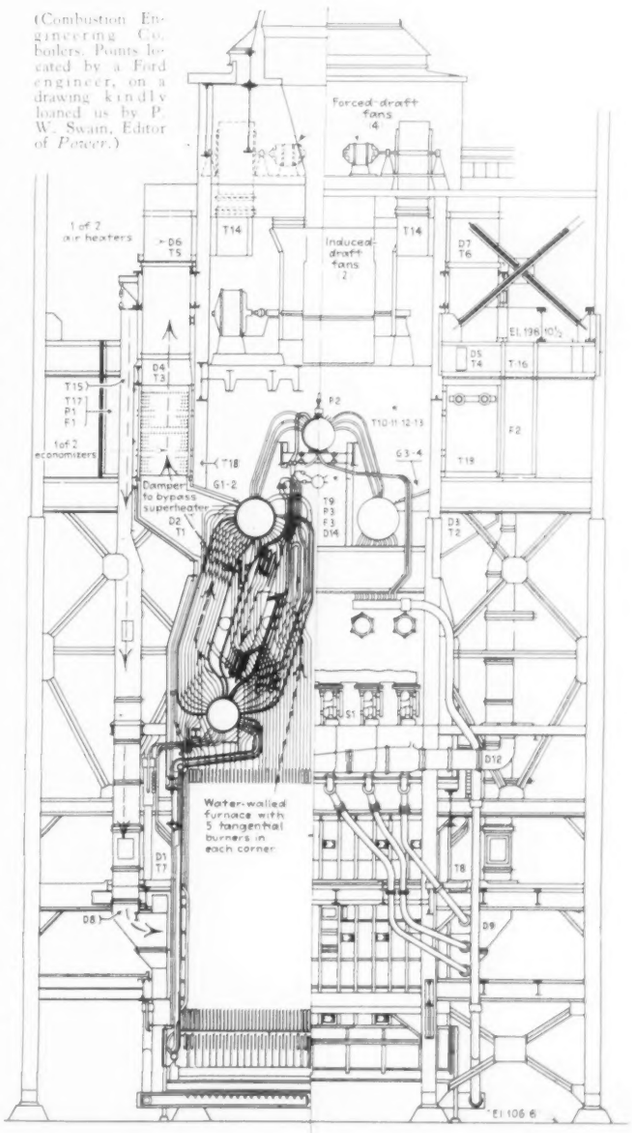
IN every power plant, large and small, instruments, meters, and automatic-control systems are becoming of increasing importance. In large modern power stations instrumentation devices of all types are so extensively used that their installations are accepted without question on the basis of economic justification. Central stations always have been prominent users of adequate metering equipment. It is in the small plant, where formerly only those meters or instruments prescribed by law were used, that an increased use of instruments and meters is most noticeable. Close attention to power costs, increasing competition for business, rising fuel costs and decreasing electric rates — all these have simulated achievements in economies of design and operation that have been built on a liberal use of instrumentation equipment.

To operate a power plant—especially a steam plant—most efficiently, the operating force must know the pressures, temperatures, flows and other measurable variables throughout the plant. This is especially true of a plant operating on a complicated heat balance, such as an industrial plant supplying both heat and power. Meters replace guesswork with accurate information for guidance to safe, continuous and proper plant operation. They give those charged with the supervision of the plant a basis upon which to direct its operation so as to achieve the best performance possible. They furnish data for calculation of the performance of the plant or any part

Fig. 1. SECTIONAL ELEVATION OF STEAM-GENERATING END OF No. 1 POWER HOUSE, SHOWING THE MOST IMPORTANT MEASURING POINTS

	Application	*Type of Primary element*	*Type of Instrument*
TEMPERATURES			
T1, T2	Gases leaving boiler	Nitrogen-bulbs	Recording
T3, T4	Gases leaving economizer	Nitrogen-bulbs	Recording
T5, T6	Gases leaving preheater	Nitrogen-bulbs	Recording
T7, T8	Furnace Temperatures	Optical pyrometers	Indicating
T9	Superheated steam	Nitrogen-bulb	Recording
T10, T11, T12, T13	Four corners of superheater	Thermocouples	Recording
T14	Air to preheater	Nitrogen-bulb	Recording
T15, T16	Air leaving preheater	Nitrogen-bulbs	Recording
T17	Feed water to economizer	Nitrogen-bulb	Recording
T18, T19	Water leaving economizer	Nitrogen-bulbs	Recording
DRAFTS (AND LOW PRESSURES)			
D1	Furnace draft	Liquid-sealed	Indicating
D2, D3	Gases leaving boiler	Liquid-sealed	Indicating
D4, D5	Gases leaving economizer	Liquid-sealed	Indicating
D6, D7	Gases leaving preheater	Liquid-sealed	Indicating
D8, D9, D10, D11, D12	Pressures, secondary air to furnace	Liquid-sealed	Indicating
D13	Pressures, primary air	Liquid-sealed	Indicating
D14	Apex draft	Liquid-sealed	Indicating
PRESSURES			
P1	Feed water to economizer	Bourdon-tube	Indicating
P2	Saturated steam	Bourdon-tube	Ind. & Rec.
P3	Superheated steam	Bourdon-tube	Indicating
FLOWS			
F1, F2	Feed water to economizer	Orifice	Recording
F3	Main steam flow	Flow nozzle	Rec. & Totalizing
GAS ANALYSES			
G1, G2, G3, G4	Gases leaving boiler	Absorption	Indic. & Rec.
SPEED			
S1	Fuel (pulverized coal) speed	Centrifugal	Indicating

SEE ALSO DETAILS OF BOILER CONTROL BOARD, FIG. 4.


Forced draft fans (4)
1 of 2 air heaters
Induced draft fans (2)
1 of 2 economizers
Damper to bypass superheater
Water-walled furnace with 5 tangential burners in each corner
El. 106-6

(Combustion Engineering Co. boilers. Points located by a Ford engineer, on a drawing kindly loaned us by P. W. Swain, Editor of *Power*.)

of the plant so that results may be correctly gaged and composed from time to time. Cost accounting systems will be based on adequate meter readings and correct cost allocations may point towards possible economies to be effected. Furthermore, they may be used to check on the internal condition of equipment and indicate when and where maintenance or repair is needed. An operating crew learns to know what readings are normal and readily detects any appreciable deviation from normal. We may now summarize the above as follows:

1. Operating guidance.
2. Economical supervision.
3. Performance calculations.
4. Costs and cost allocation.
5. Maintenance guidance.

INSTRUMENT DEPARTMENT

Our instrument department numbers fourteen men, making their headquarters at the power house.

The instrument department installs and maintains all industrial instruments in the plant with the exception of potentiometers. Thermometer tube-systems are sent back to the instrument-maker's home plant for refilling. Pressure gages of the Bourdon type are all repaired by the students of the Ford Trade School under competent supervision.

BOILER ROOM INSTRUMENTATION

STARTING with the boiler room, it is my pleasure to describe the instrumentation as installed at the Number One Power House of the Ford Motor Co., largest high-pressure, high-temperature power plant in the world.

Inasmuch as all the high-pressure boilers have similar meters and controls, a complete description of one will serve the purpose in most part. The boilers have complete equipment for the automatic control of combustion and feed water. The metering equipment for each boiler includes a boiler meter, two combination feed-water meters and boiler drum level recorders, four multiple recorders for temperature of feed water, flue gas, air inlet and outlet, water in and out of economizer, also air in and out of preheater. It also includes two multi-pointer gages, an electric CO_2 recorder and two pyrometers for indicating furnace temperature. Provision is also made for selector switches for operation of the combustion control and of the three-element feed-water control.

Three-element Feed-water Control: The basic principle of the three-element feed water control is to change the rate of feed-water flow to the boiler simultaneously with a change of steam flow from the boiler, to maintain a substantially constant steam flow-water flow relation, and to correct the feed-water flow to maintain a constant water level in the boiler drum for every boiler rating. Due to the fact that there are two independent boilers in a single setting, and but one steam outlet, it is necessary to regulate the water flow to each side individually. This is accomplished by taking solid linkage connections from the steam flow meter to each water flow meter, so that for every change in steam flow, the water flow of each side is changed one half of the steam flow change. The water flow linkage is also tied in with the water level recorder so that resultant water flow is the component of steam flow and water level changes. The meter linkage operates a small oil pilot of a hydraulic torque amplifier which in turn positions a Selsyn motor. The companion Selsyn is located in the housing of the feed-water valve and positions it in accordance with required changes commanded by the meter linkage. The control is adjusted to maintain a constant water level at all steam outputs. Protection is obtained in case of failure of current supply so that an alarm is sounded and the valve is held in the position where failure occurred until resumption of power. In case of mechanical failure the indicating Selsyn on boiler panel becomes a sender by tripping a tumbler switch, and the drum level may be regulated by the operator on the boiler panel control board.

Boiler Steam Meter: This meter was designed and calibrated to measure a flow of steam up to one million pounds per hour and its guaranteed accuracy is 2% throughout its chart range. It is equipped with a steam flow pen, two air flow pens and an integrator. The steam flow pen records the amount of steam being generated. The integrator totalizes the steam generated. The two air flow pens are calibrated to record the relative volume of air flowing through the furnace corresponding to equivalent steam flow outputs. It has a 24-hour chart (as have all of our recording instruments) recording the steam flow giving us a permanent record and also enabling the operator to tell at a glance the loading conditions of his boiler.

Feed-water Meters: These two meters measure the rate of flow to the north and south drums. On each chart is also recorded the water level within the drum. A third pen attached to one of the meters records the temperature of the superheated steam. A third pen on the other flow meter records the pressure of the superheated steam.

Feed-water Temperature Recorder: This instrument records the temperature of the feed water entering and leaving the economizer. As there are two economizers in the unit, three recording pens are necessary. The first pen records the temperature of the water entering the economizer; the second pen records the temperature of the water leaving the north economizer; the third, water leaving the south economizer. The temperature recorder has for its measuring element a helical tube coil connected by copper capilary tubing to a cylindrical bulb, the tube-system being initially charged with nitrogen gas at a definite pressure.

Flue Gas Temperature Recorder North and South Side: This temperature recording unit records the temperature of the flue gases entering its respective economizer and preheater. Each of these units are equipped with three pens. The control mechanism and principle of the temperature recorders are basically the same as explained above.

Multi-pointer Gage (North Side): This multi-pointer gage indicates the draft and pressures at nine points between the combustion chamber and the induced draft fan.

Multi-pointer Gages (South Side): This gage also measures drafts and pressures at nine different points at corresponding locations on the south sides. All pressures and drafts are recorded in inches of water. These gages enable the operator to tell at a glance whether or not his boiler is in proper balance and also the condition of drafts and pressure at various parts of the system.

Superheated Steam Galvatron and Superheater By-pass Controls: This mechanism measures, records and controls the temperature of the superheated steam. The Galvatron is a round-chart potentiometer pyrometer. It measures the temperature of the steam from thermocouples set in each of the four corners of the superheater unit. When the boiler is operating at high ratings the temperature of the steam has a tendency to exceed the operating temperature of 900° F. It is at this time that the by-pass dampers come into play. These dampers are installed in the four corners at the top of the first gas pass and can be adjusted to by-pass the hot gases from

Fig. 2. REAR OF INDIVIDUAL BOILER PANEL

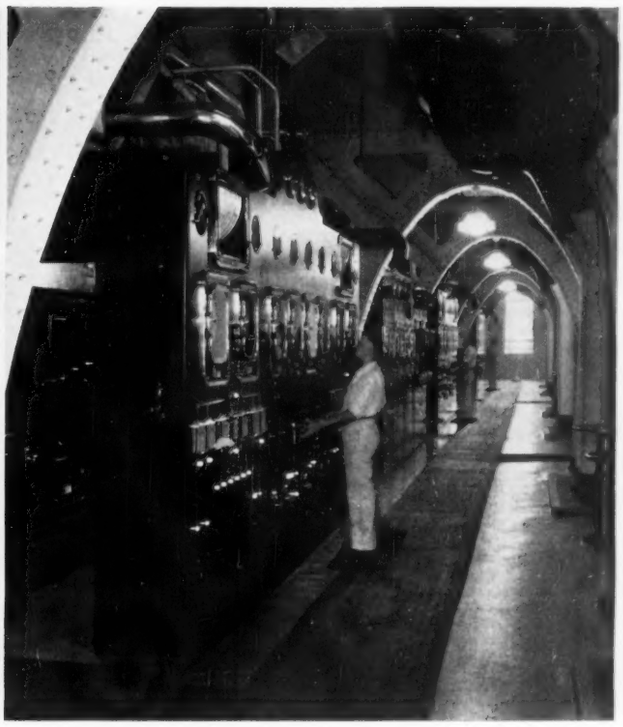
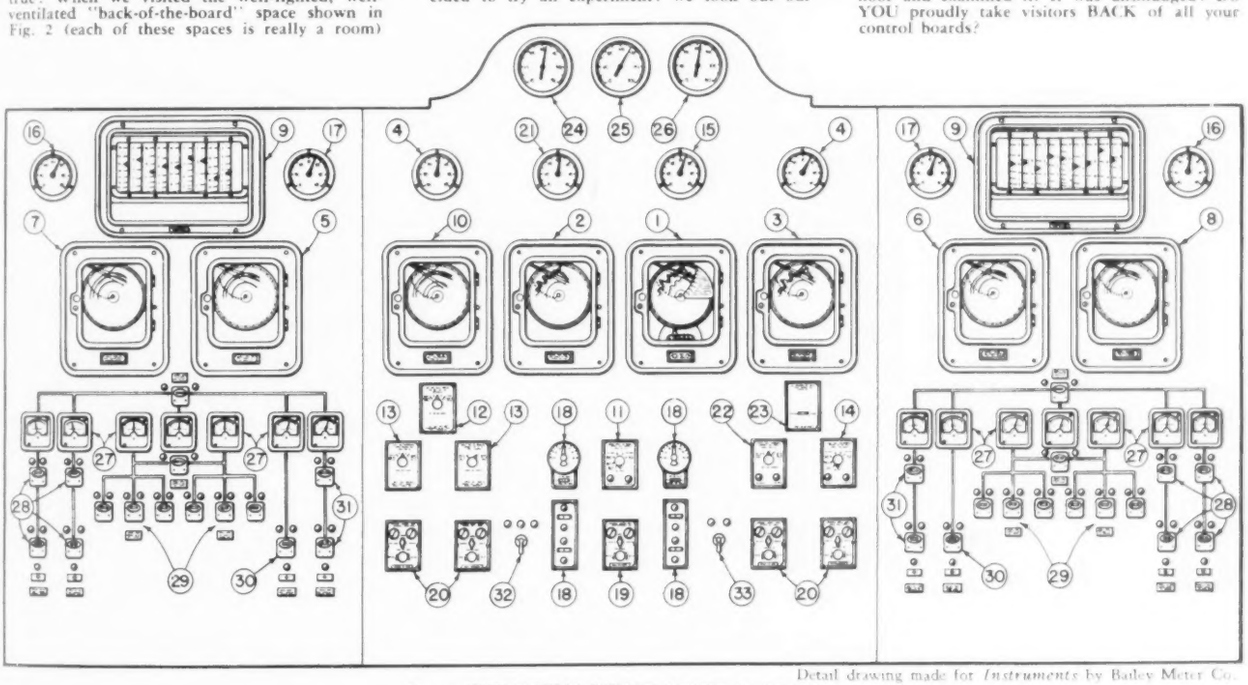


Fig. 3. AISLE BETWEEN BOARDS AND BOILER-FRONTS

EDITOR'S NOTE—Believe it or not, but it's true: When we visited the well-lighted, well-ventilated "back-of-the-board" space shown in Fig. 2 (each of these spaces is really a room) we were so struck by its neatness that we decided to try an experiment: we took out our breast-pocket handkerchief, rubbed it on the floor and examined it. It was unsmudged! Do YOU proudly take visitors BACK of all your control boards?



Detail drawing made for *Instruments* by Bailey Meter Co.

Fig. 4. INDIVIDUAL BOILER CONTROL BOARD

1. Boiler meter—indicates, records and integrates steam flow and records air flow through both sides of twin set boiler.....Bailey
2. Feed water meter, boiler water level recorder and steam pressure recorder .....Bailey
3. Feed water meter, boiler water level recorder and steam temperature recorder .....Bailey
4. Boiler drum water level indicator.....Bailey
5. Feed water temperature recorder.....Bailey
6. Air temperature recorder .....Bailey
7. Flue gas temperature recorder.....Bailey
8. Flue gas temperature recorder.....Bailey
9. Multi-pointer gage for indicating ten pressures and drafts.....Bailey
10. Zone temperature recorder for superheated steam temperatures...Bailey
11. Boiler drum switch .....Bailey
12. Transfer drum switch .....Bailey
13. Transfer drum switch for forced draft.....Bailey
14. Drum switch for burner damper.....Bailey
15. Fuel control drive position indicator.....Bailey
16. Forced draft control drive position indicator.....Bailey
17. Induced draft control drive position indicator .....Bailey
18. Three-element feed water control valve position indicator and signals .....Bailey
19. Master superheat control bypass damper selector valve.....Bailey
20. Individual superheat bypass damper selector valves and position indicators .....Bailey
21. Selsyn-operated turbine signal.....Bailey
22. Primary air drum switch .....Bailey
23. Induced draft synchronizing switch.....Bailey
24. Saturated steam pressure gage.....Ashcroft-Hancock
25. Feed water pressure gage.....Ashcroft-Hancock
26. Superheated steam pressure gage.....Ashcroft-Hancock
27. Ammeters, Type AD7.....G-E
28. Forced draft fan turn and pull switches, Type CL-1.....G-E
29. Coal feeder turn and pull switches, Type CL-1.....G-E
30. Primary air turn and pull switches, Type CL-1.....G-E
31. Induced draft fan turn and pull switches, Type CL-1.....G-E
32. Root valve control switch, Type W.....Westinghouse
33. Stop and check valve control switch, Type W.....Westinghouse

Added later: CO_2 indicator (see Fig. 3, topmost dial) and recorder (visible through glass door in Fig. 2).....Leeds & Northrup

the top of the first pass to the third pass. These four by-pass dampers are controlled by air-operated selector valves, which may be operated as a unit or individually. The selector switches are operated on the boiler panel control board. The four-zone Galvatron recorder is used as a guide in determining whether or not the dampers are in step. If not, they may be made so by individual adjustment.

Central Control Switch: This is a six-way-throw drum switch, which controls:

1. The rate of the fuel fired to boiler.
2. The vanes of the induced draft fans.
3. The vanes of the forced draft fans.

By further adjustment of switch the boiler may be placed on:

4. Remote manual control.
5. Semi-automatic control.
6. Fully automatic control.

I might add at this point that due to the extensive use of a-c. motors on the high-pressure installation we have two speeds, high and low, on our motors. Any intermediate range in case of our fans is taken care of by the adjustment of vanes on the fan itself which limits the capacity to that desired.

Through the utilization of transfer switches or "individual switches" it is possible to take any fan or group of fans off of automatic control in case it is desired to have them run at constant speed or kept out of service entirely.

Burner Damper Drum Switch: This drum switch operates the dampers in the preheated air duct. The purpose of these dampers is to create and maintain a positive pressure in the air duct. These four dampers—one in each corner directly behind the coal burners—may be operated individually or as a single unit.

Fuel Feed Control Drive Position Indicator: Each of the twelve pulverized coal feeders is driven by a 2 h.p. variable-speed motor, their speed being controlled collectively by a banked grid rheostat operated by a control drive. For each motor there is an individual rheostat in the bank, the contact arms on all of them being connected to the same shaft and driven together by the control drive. However, each grid can be shifted in the frame, with respect to the others, so that the relation between speeds of the various motors can be varied to compensate for wear on the feeders or other conditions. The indicator denotes on the panel board the position of the fuel feed rheostat.

Forced Draft Control Drive Position Indicator: This indicator denotes the position of the vanes on the fans as to amount of opening.

Induced Draft Control Drive Position Indicator: Operates same as the one on forced draft fans.

Turbine Signal: Through this indicating device the generator operator can give advance notice of his intentions to the boiler operator. This enables the boiler operator to be prepared to act when changes are made in placing the generator on or off the line.

Pressure Gages: There are three Bourdon type gages mounted on each panel board indicating Feed Water Pressure, Saturated Steam Pressure, and Superheated Steam Pressure.

CO_2 Meters: Just above the three pressure gages is located the indicating dial of an electric CO_2 meter, using the thermal conductivity method. A self-balancing principle is employed, permitting the installation of both a recorder and an indicator, each located at any distance from the boiler. The large indicating dials are at the top of each boiler control board; the recorders are on the walls of alcoves off the Main Aisle between the boiler fronts and the main control boards (see Fig. 2).

Fan Control Switches: All fans are cut in and out of operation by the manipulation of control switches. These fans include: forced, induced and primary. Each individual coal feeder is also controlled by a similar switch.

Root Valve Control Switch: On each high pressure boiler is a motor operated Root valve, its purpose being to keep the steam from backing up into the boiler when it is out of service. This valve may be opened and closed from the operating panel board and acts as a safety check and stop valve.

Stop and Check Valve Control: This is a motor operated valve operated from the panel board also. It serves the same purpose as the Root valve in that its purpose is to protect the boiler.

SUMMARY

To sum up the instruments as used on the control panels of our high-pressure boilers we have the following:

Type of Instrument	*No.*	*Use*
Recording Gages	1	Steam Pressure
Recording Gages	18	Boiler Drafts
Recording Gages	3	Steam Pressure
Indicating Gages	2	Primary Fans
Indicating Gages	16	Boiler Controls
Ammeters	6	Coal Feeders
Ammeters	8	Fans
Ammeters	6	Dampers
Position Indicators	6	Fans
Position Indicators	6	Dampers
Position Indicators	2	Water Levels
Temperature Recorders (2 bulbs—16 thermocouples)	6	Flue Gas
	3	Air Pre Heater
	3	Water
	6	Steam
Indicating Thermometer	1	Steam
Pyrometers	2	Furnace Temperature

REMOTE CONTROL

There is a tendency towards remote control of power plant equipment, with all important instruments centralized. Here at Ford's we have a master panel board which gives at a glance the pressures in the main headers feeding the three high-pressure turbines. Also the pressure on the header fed by four 250-lb. boilers. These are clock-operated recording instruments. Electric flow meters, also incorporated in this main panel board, record the flow of water in the low-pressure boilers. Two flow meters record the flow of water in the east and west radiant boilers. Two meters record the flow of water in the boilers proper east and west. These meters do not totalize but are capable though selector switches of recording the flows of four boilers on one chart.

Along the top of the board, pressure gages indicate

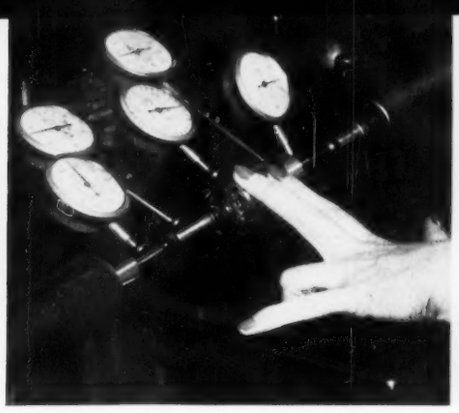
1. Vacuum
2. Air
3. Service Steam
4. Main Steam
5. Feed Water Low Pressure
6. Fire Service
7. Mill Service
8. City Water

A clock completes the main panel board.

Regarding remote readings indicated in various parts of this article: We choose to use the Selsyn motor. Transmitting and receiving elements are Selsyn motors having interconnected stator windings and being connected to a single-phase a-c. line. Three conductors are required between the stator windings of transmitting and receiving motors. The Selsyn system is used to indicate the positions of water level recorders, rheostat position on coal feeders, turbine signal, water level indicators and fan vane position.

In a large plant such as this, one will find individual gage boards distributed in various parts of the plant. No attempt will be made at this time to describe them but this will be left for subsequent articles.

Checking against Johansson blocks the gages used in motor manufacture.



Inspecting rotors of fractional-horsepower motors for concentricity at five points.

Inspecting rotors of fractional-horsepower motors for dynamic balancing.

Instrumental Testing and Inspection in the Manufacture of Induction Motors

By R. L. STRODE
River Works, General Electric Co., West Lynn, Mass.

SINCE the induction motor has such extensive fields of application, methods used by one manufacturer to measure and control its fabrication may interest *Instruments* readers. The motor is commonplace in a complete range of sizes from tiny fractionals to units of hundreds of horsepower. The descriptions in this article apply particularly, however, to integral ratings of one to fifteen horsepower, synchronous speed range 750 to 3600 r.p.m. and frequencies 25 to 60 cycles. The popularity of the induction motor is due not only to its moderate first cost but to its record for long life, low cost of maintenance and high efficiency — when properly designed, manufactured and applied. It is a highly competitive article of manufacture, both as to cost and delivery. Sales of special designs conforming to a customer's specifications are often closed on the basis of prompt delivery, and deliveries are measured in days. Measurement and control methods must therefore combine accuracy, low cost and speed.

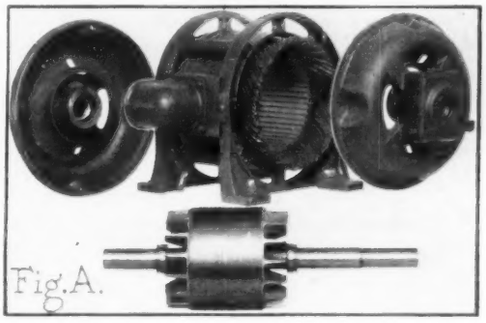


Fig. A.

In its most common form, the motor is an open, horizontal foot-supported model (Fig. A) with grease-lubricated ball bearings or with sleeve bearings and oil rings. For some kinds of service, sleeve bearings with wool waste as an oil feeder are popular. In addition to the open design, there are such trade modifications as splash-proof, totally-enclosed, totally-enclosed fan-cooled, explosion-proof, loom drive, screenless textile — which names are descriptive of service. Practically all designs are available for vertical mounting (ring, tripod and four-foot) and for horizontal footless assemblies in which one end shield is flanged or has arms for bolting on.

The instrumentation problem can be segregated into four general, although somewhat overlapping, classifications: development and proof testing of complete new designs; development and testing of improved parts and processes for application to existing designs; testing and control to insure performance to existing standards; and special tests with inspections as required by customer's particular specification.

For the work of development and control, in addition to the company's Research Laboratories, there are available such facilities as strength of material equipment, Metallurgical Laboratory, control of casting sands, testing of wire and its several insulating coatings, control of insulating varnishes, calibration of electrical instruments, speed-measuring devices and mechanical inspection tools and fixtures, noise study and control, vibration measurement, motor life tests and specific performance testing under both normal and such severe conditions as excess moisture, acid, alkali, abrasive dust, etc.

This outline of facilities suggests some of the specific performance factors which are usually important and may be subject to guarantee: efficiency, power factor, starting torque and current, maximum output, speed under load, heating, noise, vibration, accuracy of dimensions, etc., together with the manufacturing ideal of minimum cost, long life, moderate maintenance and rapid manufacture.

The magnetic structure of both stator and rotor (see Fig. A) consists of laminated sheets of high-permeability, non-aging, silicon steel. The mill manufacture of this steel is supervised by a corps of resident experts and, in addition, control samples of every lot shipment are given an Epstein Test (Fig. 1) at the factory to insure a low core loss requirement.

The material and construction of the dies used to punch this hard steel is itself a problem for experts. Even the burr, formed at the cut edges if punch or die become dull, must be controlled because, if it accumulates, eddy current losses may impair motor performance. To measure the burr, optical equipment accurate to 0.00025″ has been developed as an improvement over the older and not-so-precise micrometer determination.

The end frames of the induction-motor stators are of malleable iron, the core structure held rigidly by four heavy rivets. During the design stage of the development, these parts received such tests as indicated in Figs. 2, 3 and 4. These tests for rigidity are important because for

high electrical performance the clearance (air gap) between stator and rotor should be as small and as uniform as practical. Frame rabbet (end shield fit) and stator bore must be held to close tolerances of size and concentricity. Stator bores are precision ground, reference for fixture location being the rabbet groove. Proof of size and concentricity is determined by checking fixtures, of which Fig. 5 shows a type.

The manufacture of the copper wire, with which the stator is wound, is controlled at every step. Wire is mill drawn, but protective coatings are factory applied. Enameled wire with additional fibrous cushion coatings is commonly used. Samples of every lot of enameled wire are tested for uniformity, continuity and flexibility of coating. Fig. 6 shows some of the equipment. In the center foreground is an abrasive testing machine and at the right rear is apparatus for checking continuity of coating by electrical contact. Proper application of the liquid enamel required many developments, among them automatic control of viscosity. Cushion coatings such as paper, cotton, silk and asbestos also are tested.

Stator coils are random wound on high-speed winding machines, important factors being accuracy of turn count, non-abrasion of insulation and minimum wire stretch. All such factors are measured.

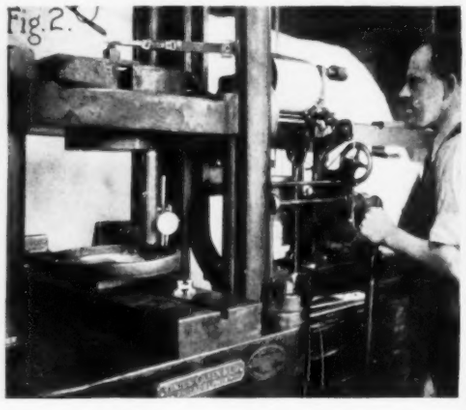
Insulating varnishes which bond the coil conductors and protect the whole unit are almost as important to motor life as wire insulation. Desirable properties such as bonding ability, non-aging, high heat conductivity, resistance to moisture, oil, acid and alkali and abrasive dusts have been developed in the laboratory, but additional checks are made at the factory, the dust box (Fig. 7) being an example.

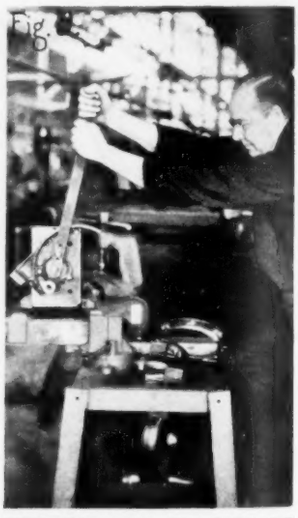
During the varnish impregnating cycle, time and temperature are controlled. The baking cycle now has been reduced to almost one-third the time previously required, and in addition to valuable manufacturing time saved, a better product resulted.

The rotor is usually of the squirrel-cage type shown in Fig. A, but wire-wound rotors, with rings and an external resistance for speed control under load, also are built in quantity. In the standard squirrel-cage type, the conducting element is aluminum alloy of rigidly specified composition and conductivity, pressure-cast into position so that troublesome joints are entirely eliminated. Close control of conductivity of aluminum is important because for a given set of performance conditions, a closely-determined resistance is needed. Small amounts of impurities vary the specific resistance of aluminum through a wide range. Pig purchases are made under rigid conductivity specifications and every lot is factory laboratory tested before a release for casting is given. Fig. 8 shows the aluminum resistance measuring equipment designed for that work.

The casting problem is further complicated by molten aluminum's chemical activity in picking up impurities and by its rather critical pouring temperature. To minimize contamination, melting pots and pouring ladles are enameled and the enamel is frequently renewed. Electric melting furnaces are used, with automatic temperature control and signal lights as an additional safeguard.

To aid in smoothing out motor torque values during rotor acceleration under load, and to reduce noise, rotor bars are cast at a skew angle with relation to the stator slots. This angle is controlled within close limits at the time of lamination assembly.





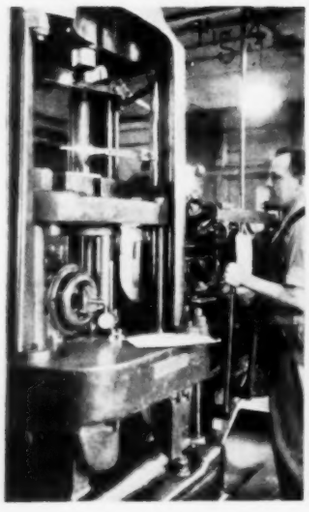
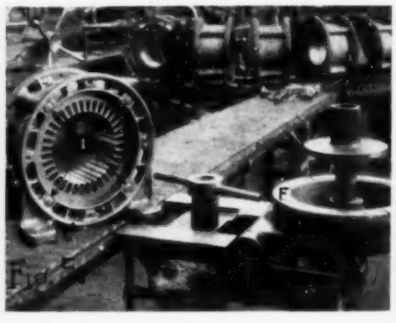
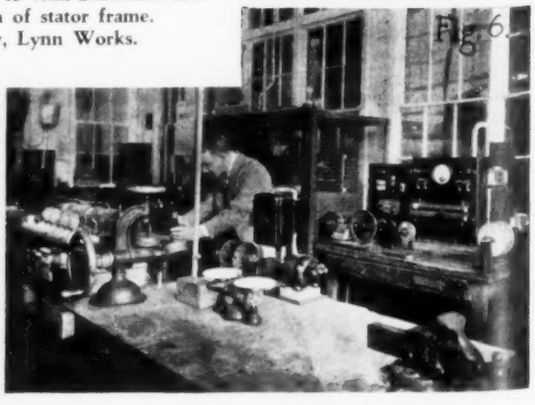
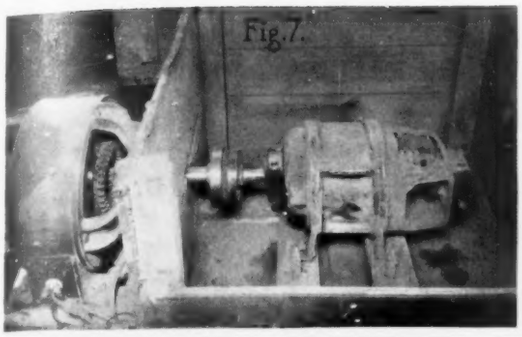
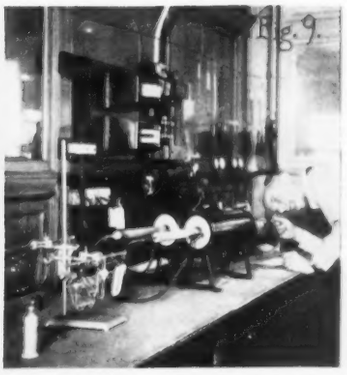


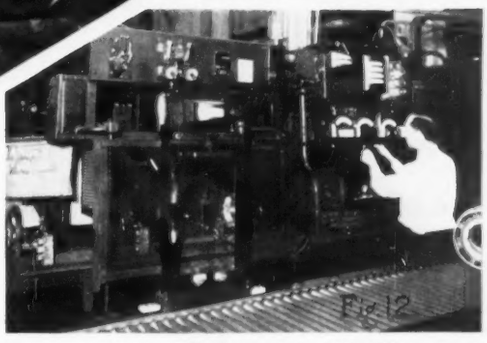
Fig. 1. Epstein Test Set for silicon-steel laminations.
Fig. 2. Load deflection test on a-c. motor end frame foot.
Fig. 3. Bending test on a-c. motor end frame.
Fig. 4. Induction motor being subjected to load-deflection test.
Fig. 5. Checking diameter and parallelism of stator frame.
Fig. 6. Insulation Engineering Laboratory, Lynn Works.

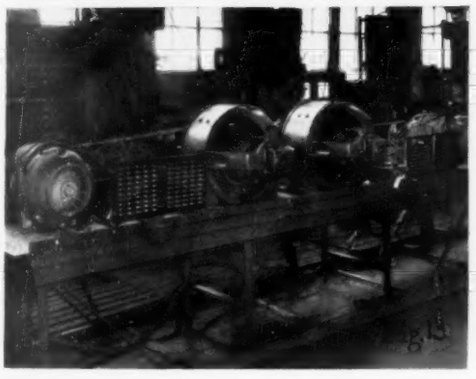












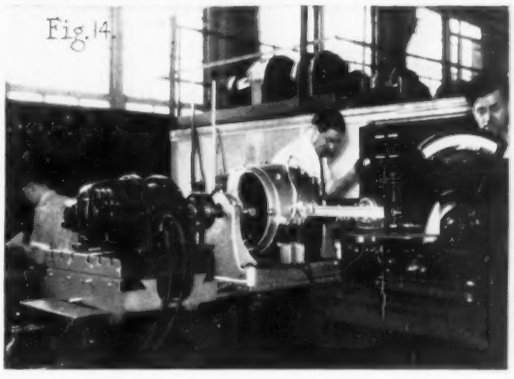


Fig. 7. Testing motors under extremely dirty and abrasive conditions.

Fig. 8. Test for conductivity of aluminum.

Fig. 9. Determining carbon content of steel.

Fig. 10. Checking bore in a-c. motor end shield.

Fig. 11. Checking end shield concentricity and tilt.

Fig. 12. High-potential, resistance, and phase-balance test for white stators.

Fig. 3. Measuring temperatures in totally-enclosed fan-cooled squirrel-cage induction motor, for heat-flow.

Fig. 14. Dynamometer test on wound-rotor induction motor.

Service dictates shaft materials: high-quality regular shaft steel, tool steel, stainless steel, even non-ferrous alloys. Purchase is by specification with check tests on receipt, the test for carbon being shown on Fig. 9, and by strength tests. Shafts are precision ground, diameter tolerances to 0.0005″ being the rule. Lot production is checked with "go" and "no go" limit gages which in turn are frequently checked against laboratory block standards.

End shields are usually of cast iron (steel or aluminum for some services). In that portion of the foundry where continuous moulding is carried on, a floor laboratory has been set up for the control of molding sand. Every fifteen minutes during the molding day, tests are made for moisture, permeability and green strength in compression. Test results regulate additions of green sand and moisture.

All end shield machining must be accurate to close limits. Fits that affect the position of the rotor in this stator must be concentric. Typical checking fixtures are shown in Figs. 10 and 11.

For the general control of factory windings, Fig. 12 shows the equipment for testing stators just before varnish impregnation. Its features are an automatic high-potential ground test and a manual determination of phase balance and resistance. The automatic high-potential test is considered so important that it is repeated after parts are assembled into a complete motor. It thus becomes a portion of the final performance test data.

Fig. 13 indicates how elaborate a test may be required, when heating conditions in all parts must be studied. Thermocouples have been placed at all essential locations on the motor and each couple is wired into a plug board so that accurate and rapid temperature reading may be taken during the heating cycle.

Fig. 14 shows one form of a dynamometer as set up to measure the efficiency of a motor.

Manufacturing and control standards having been set and electrical characteristics determined from complete test data, duplication of electrical performance in a standardized motor can be assured by three sets of readings. These are stator resistance, power input with rotor locked and power required to operate the motor without load. These test readings are taken as a record of every motor built and then compared with the standard data. Other data as may be required are recorded also for all motors on which standard data have not been determined or about which test information beyond the usual is needed.

As a final factory operation, an overall inspection is made. Not until then are rating nameplates attached—a guarantee that quality manufacturing obligations have been met.

The Rockwell Hardness Testing Method

By S. R. WILLIAMS
Professor of Physics, Amherst College

THE ROCKWELL HARDNESS TESTER

This hardness measuring device[1] has attained an enviable reputation because of its speed, accuracy and wide range of adaptability. Figs. 108 and 109 show two models for general purposes. "The Rockwell hardness number is based on the additional depth to which a test point or ball is driven by a heavy load beyond the depth to which the same penetrator has been driven by a definite light (initial) load."

Penetrator "C"—For exceptionally hard bodies the test-point is a sphero-conical diamond. It is made from a selected diamond, ground and polished accurately to a cone of 120° angle with a mechanically lapped spherical point. (See Fig. 110.) It is still referred to sometimes as the "Brale Penetrator" but is now officially designated as penetrator "C" and will thus be referred to in subsequent discussions. The standard major load for the "C" penetrator, the diamond point, is 150 kilograms.

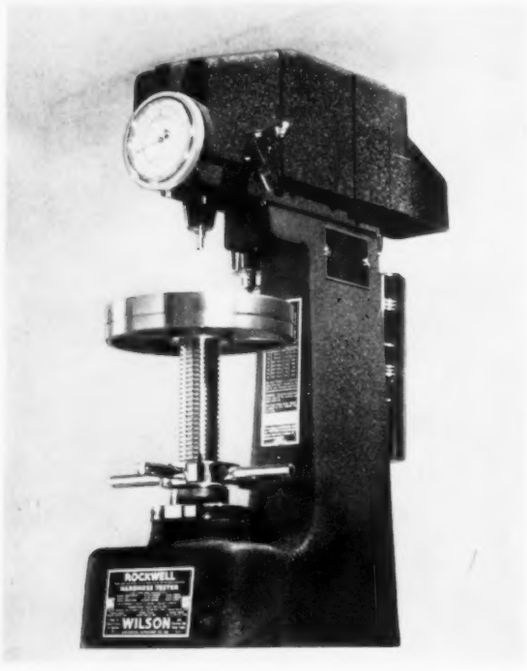


Fig. 108. The Rockwell hardness tester. A model with eight-inch vertical capacity.

Penetrator "B"—For unhardened steels, phosphor-bronze, brass, cast iron, and many metals or alloys that are not extremely hard, a specially hardened steel ball, 1/16″ in diameter, is used as a penetrator, hereafter to be known as penetrator "B". This ball is mounted in a steel chuck designed to permit replacement or change of balls in a few seconds. The standard major load for the "B" penetrator, the 1/16″ steel ball, is 100 kilograms.

Special Penetrators—For making special comparative tests, the Rockwell hardness testers can be furnished with ball penetrators of 1/8″, 1/4″ or 1/2″, and these may be used with 150-kg., 100-kg. or 60-kg. major loads. The use of the diamond cone is only for exceptionally hard materials on whose surfaces, even with the 100-kg. major load, a steel ball would tend to flatten. On hard tool steel, for instance, Penetrator "C" is much more sensitive than the steel ball penetrator because the diamond holds its shape and permits the use of a 150-kg. major load. Also, on a machine which makes the depth of the impression a measure of hardness, the diamond cone indenter makes an impression which is deep in proportion to its diameter. Nevertheless, much industrial testing is being done with the 1/8″, 1/4″ and 1/2″ ball penetrators and the various major loads, and such tests have lately been written into some specifications.

Fig. 109. A Rockwell hardness tester with 3¼″ vertical capacity.

Fig. 110. Penetrator "C." This is a sphero-conical diamond point indenter, ground and polished accurately to a cone of 120° angle with a mechanically lapped spherical point of 0.2 mm. (0.008″) radius. The term Brale, applied to this penetrator, is a registered trade mark. The 150-kg. load is used with this indicator for C-scale testing. This illustration twice actual size.

[1] S. P. Rockwell, The Testing of Metals for Hardness, *Transactions American Society for Steel Treating*, August 1922, pages 1013-1033.

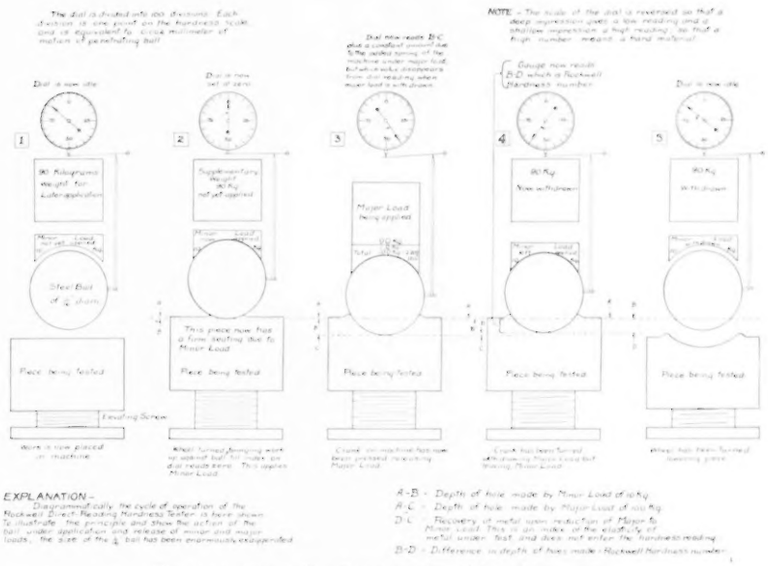


Fig. 111. Principle of the Rockwell hardness tester.

MAKING AN INDENTATION WITH THE ROCKWELL TESTER

In order to eliminate errors in the measurement of the depth of impression made by either the ball or the cone indenter, due to surface imperfections of the work or varying qualities of contact between the work and penetrator, the Rockwell is designed to make two superimposed impressions—one with a load of 10 kg. and the other with a load of either: *(a)* 100 kg. when the 1/16″ steel ball "B" penetrator is used, or *(b)* 150 kg. when the diamond cone test point of 120° angle is used. This procedure is shown by a diagram in Fig. 111. No. 1 shows the sample placed on the elevating screw. By turning up the elevating screw the test piece is brought into contact with the penetrator until a load of 10 kilograms has been brought to bear on the penetrator as shown in No. 2. The ball or cone indenter sinks into the surface to the extent A-B. The dial is set to zero and then the major load is applied as in No. 3, and the penetrating surface of the ball sinks to a further depth of B-C. In No. 4 the major load is removed and due to the elastic property of the material tested the ball rises a distances C-D and there it rests until the depth of the indentation due to the excess load of 90 kilograms has been measured. The depth is shown as the distance B-D in No. 4. Finally the elevating screw is lowered as in No. 5 and the test piece is removed in order that another piece may be put in its place and tested. The same process is carried out when the diamond indenter is used, only in this case a supplementary load of 140 kilograms is added as shown in No. 3 for the supplementary load of 90 kilograms. The depth, B-D, is a measure of the hardness of the sample tested.

Fig. 112 shows the successive steps in making a Rockwell hardness measurement. The numbers given in the directions correspond to those of the parts—on the illustration—which are to be moved or operated in the process of making a measurement.

The Rockwell is not a press with a depth measuring attachment. It is a precision measuring machine with a press as one of its features. The whole system is one of weights and levers for impressing a given load on the indenter. It is well known that, in determining the hardness of the softer metals by measuring any dimension of any impression in any indentation method, the load should be applied both slowly and smoothly. There is an oil dash-pot system on each Rockwell which controls the smooth application of the load and is adjustable so that the load may be applied as quickly as in two seconds or as slowly as desired. Except on the softer metals it is customarily applied in about six seconds.

1. Place piece to be tested upon anvil or testing table.

2. Turn wheel to elevate work into contact with test point and continue turning and forcing against penetrator till index 8 shows that Minor Load is applied.

3. Turn bezel of gage to set dial zero behind pointer.

4. Push handle back an inch to release and apply Major Load.

5. Observe when moving pointer comes to rest, then—

6. Pull handle forward, thereby removing the Major but not the Minor Load.

7. Read "Rockwell" Hardness Number on the dial.

Note—The red figures on dial are always used for any ball penetrator and black figures for the "Brale" penetrator.

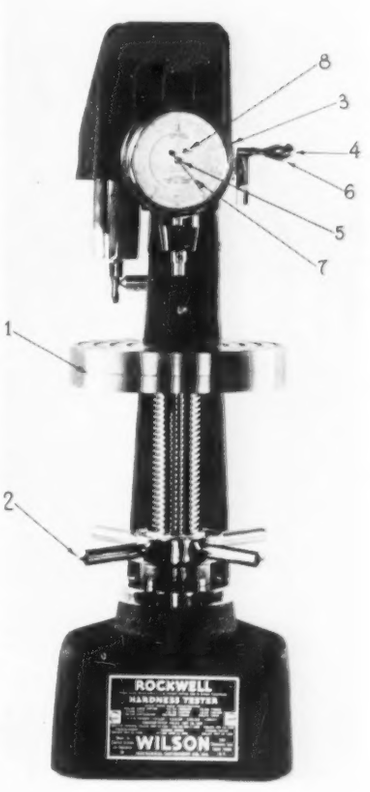


Fig. 112. Directions for making a hardness measurement with the Rockwell hardness tester.

Fig. 113 shows another way in which the increment of depth of the indenter, due to the major load, may be graphically represented. The same line of reasoning holds for the steel ball indenter as for the diamond cone.

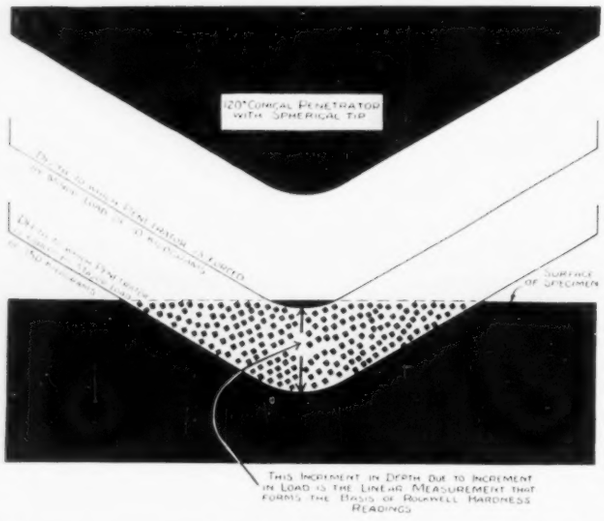

120° CONICAL PENETRATOR WITH SPHERICAL TIP
SURFACE OF SPECIMEN
THIS INCREMENT IN DEPTH, DUE TO INCREMENT IN LOAD IS THE LINEAR MEASUREMENT THAT FORMS THE BASIS OF ROCKWELL HARDNESS READINGS

Fig. 113. Increment—Not Total Depth. Hardness testing on the Rockwell hardness tester is based upon the measurable increment of depth of penetration due to increment of load. In the case of hard steel the penetrator is a diamond cone with spherical tip of minute but definite radius. The first load applied is 10 kilograms and the second 150 kilograms; so that the increment is 140 kilograms. The increment of depth due to increment of load is 0.00008″ for each point of hardness on the Rockwell scale. If a piece of steel is as hard as Rockwell C58 at one spot and C55 at another it means that the depth of penetration is three times 0.00008″ or 0.00024″ deeper at the softer spot; but that information is given in terms of hardness on the dial.

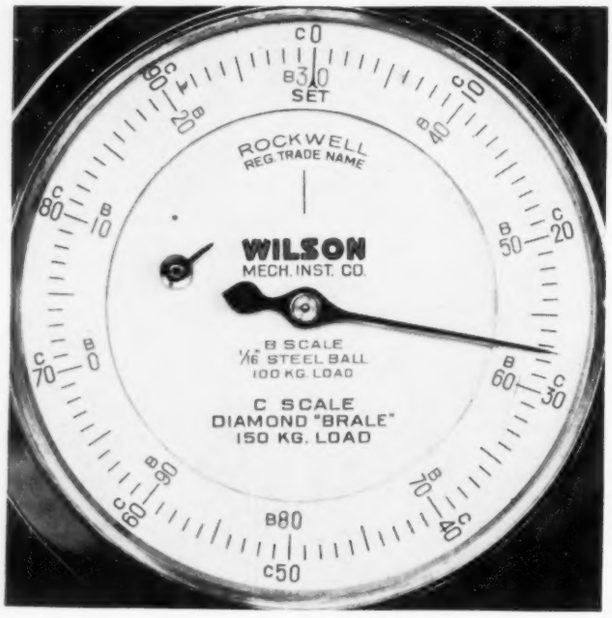


Fig. 114. The direct-reading dial for the Rockwell hardness tester. The "B" readings are to be used with the ball penetrator while the "C" scale serves for the diamond penetrator.

The direct-reading dial (see Fig. 114) has two scales. The "B" scale in red applies with the "B" penetrator and 100-kg. load. The "C" scale in black applies with the diamond cone penetrator and 150-kg. load. Both by letters and colors the "B" and "C" scales are distinguished on the dial and all notations of readings should be invariably written down with the prefix "B" or "C". For example, there is no Rockwell hardness No. 42. There is a Rockwell hardness No. B-42 and a very different Rockwell hardness, No. C-42. The letter is quite as necessary as the numeral in designating the Rockwell hardness number.

Fig. 115. The pitch of the elevating screw of this jack, shown at the left, is identical with the pitch of the elevating screw in all models of Rockwell testers.

For specific purposes there are special scales on the Rockwell machine, although these have been standardized and are well understood. The letter and number of these special scales must always be given, otherwise the hardness numbers have no meaning. The following table gives the designation for the various scales of the Rockwell Hardness Tester.

DESIGNATIONS FOR THE VARIOUS SCALES OF THE ROCKWELL HARDNESS TESTER (MAY 1938)

Scale Symbol	*Penetrator*	*Major Load, kg.*	*Dial Figures*
B	1/16″ ball	100	Red
C	"Brale"	150	Black
A	"Brale"	60	Black
D	"Brale"	100	Black
E	1/8″ ball	100	Red
F	1/16″ ball	60	Red
G	1/16″ ball	150	Red
H	1/8″ ball	60	Red
K	1/8″ ball	150	Red
L	1/4″ ball	60	Red
M	1/4″ ball	100	Red
P	1/4″ ball	150	Red
R	1/2″ ball	60	Red
S	1/2″ ball	100	Red
V	1/2″ ball	150	Red

SURFACE PREPARATIONS

It is desirable to have as smooth, plane and clean a surface as possible when using the Rockwell machine. All small ridges or scale should be removed, because the scale helps to break the surface without plastic flow and thus discordant results are obtained. Ordinary machined surfaces are quite satisfactory. All forms of dirt, particularly gritty particles, are to be avoided in the contact surfaces between the indenter and the material to be tested, for the same reason that scale is to be avoided.

SPECIAL PARTS AND ACCESSORIES

Anvils—The disk on top of the elevating screw is called the anvil. See Figs. 108, 109, 112 and 123 and note the different sizes. Four anvils are furnished with each Rockwell instrument. In some cases the anvils have a V-shaped top in which round rods and tubing may be placed so as to insure centering of the penetrator on the upper surface of the cylindrical rods or tubes. See Fig.

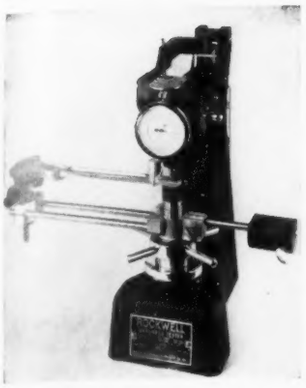


Fig. 116. An auxiliary work support which moves up and down in an undisturbed position relative to the anvil.

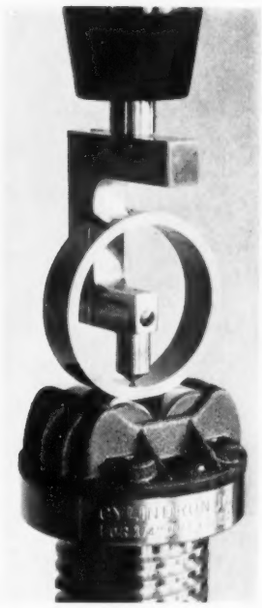


Fig. 117. A standard goose-neck adapted for holding the indenter when measuring the hardness of the inner surfaces of rings and tubes.

115. In testing thin soft sheet metal a special anvil is recommended. This consists of a steel plate with a polished diamond surface inset at the center of the anvil. For testing reamers, drills, and many tapered and irregular pieces, it often is necessary to have an anvil which can so be adjusted that the line of thrust of the indenter will be at right angles to the surface to be tested. Some such accessories may be made in a good machine shop but it is well to bear in mind that the Rockwell instrument, like all indentation-hardness testers, is sensitive to vibrations: if special accessories are added to the machine, care must be exercised in not adding extra sensitiveness to vibrations and thus obtaining false readings.

Work Supports—Frequently, one wishes to test long flat bars and cylindrical rods. They must be held in a level position on the anvil even when the test is being made on the end of the bar or rod. For such measurements certain adjustable, auxiliary work supports are provided. Fig. 116 shows one which is attached to the elevating screw and therefore maintains a fixed position relative to the anvil. In Fig. 115 is shown a more flexible support since by means of two such adjustable jack rests, long rods may be tested at the middle while each end is supported by one of these jacks. The pitch of the elevating screws of the jacks is exactly the same as the pitch of the elevating screw of all Rockwell testers.

Goose-necks—The problem of measuring the hardness of the inner surface of rings and cylinders presents some difficulties, because the ring itself gets in the way of the shank to which the indenter is attached. To obviate this difficulty, different forms of goose-necks have been devised which may be attached between the thrust pin of the tester and the indenter. Fig. 117 shows a regulation goose-neck supplied for the general type of Rockwell tester; Figs. 118, 119 and 120 show special forms of goose-necks for special purposes.

Test Blocks—Finally, after all the accessories have been attached, all parts have been inspected and everything seems to be in readiness for making a hardness measurement, there still remain the questions: will the

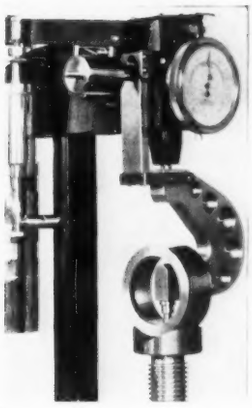


Fig. 118

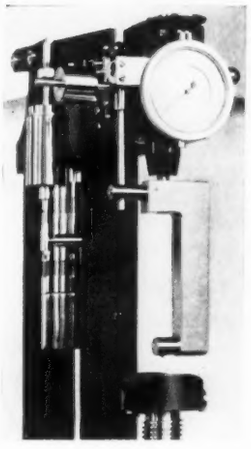


Fig. 119

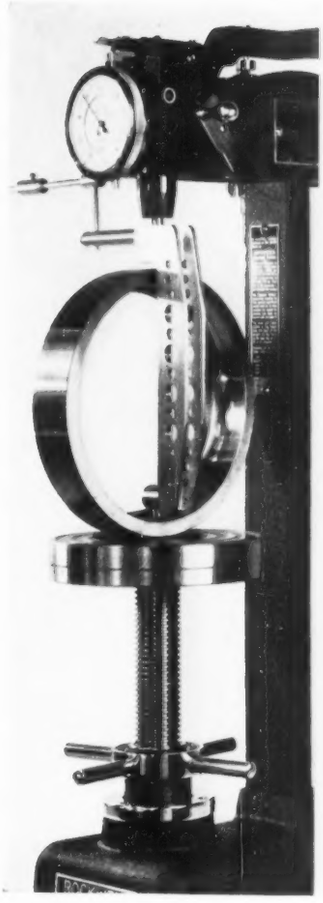


Fig. 120

Figs. 118, 119 and 120. Special forms of Rockwell testers and the special goose-necks to be used when measuring the inside surface of a ring or hollow cylinder in case the outside diameter exceeds two inches. These special testers are arranged to compensate for goose-neck weight in order to preserve standard loads. The goose-necks, too, are of special design and construction: stiff and properly aligned. (Home-made goose-necks frequently are a source of errors and troubles.)

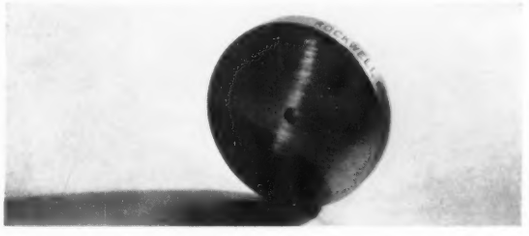


Fig. 121. Rockwell test blocks are made of different materials, each with known hardness values. The accuracy of one's Rockwell hardness tester can easily be checked.

reading found correspond to other machines?; can duplicate readings be obtained by other machines? Where no second machine is available for checking, test blocks are provided whose hardnesses have been tested by standard machines and so a means for testing the accuracy of a Rockwell machine is readily at hand and the tester can and should be frequently checked. Fig. 121 shows such a test block.

In Fig. 122 is shown an improvement relently put on the Rockwell instruments. It is the plunger rod system whereby the load is applied directly to the indenter with little or no friction from the bearings of the rod. This is a particularly important improvement on the

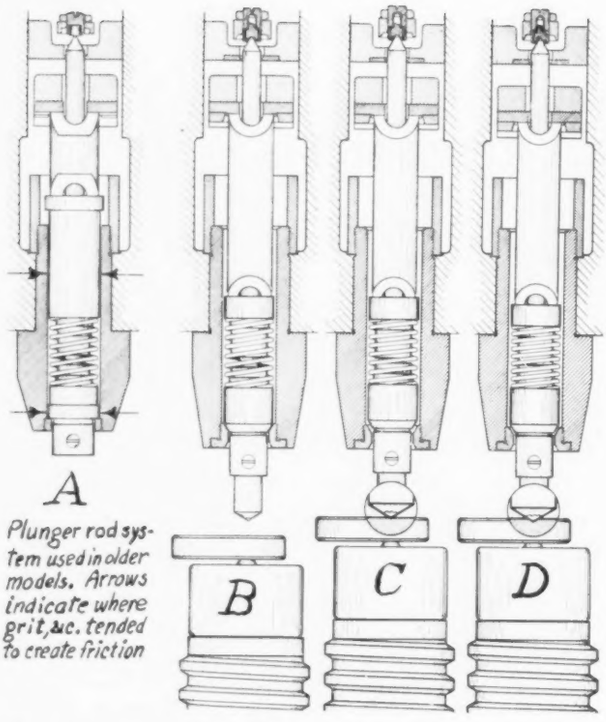


Fig. 122. The newer full floating frictionless plunger rod system is shown in the three figures, B to D. Fig. B shows position of plunger rod with specimen not yet in contact with penetrator, i.e., before minor load is applied. Fig. C shows position when minor load is first applied. Fig. D shows its position when major load is applied and approximately its position at the conclusion of test when load has been reduced again from major to minor and hardness reading is observed.

Rockwell Superficial machine inasmuch as the force necessary to overcome the friction plays a larger rôle than in the regular machines.

ROCKWELL SUPERFICIAL HARDNESS TESTER

The rapid development of the nitriding process for the surface hardening of steels called for a sensitive but rugged device capable of measuring the hardness of the surface itself, not the hardness of a thick layer. In the Rockwell line of hardness testers shown in Fig. 123, the Wilson Mechanical Instrument Co. has developed this type of surface hardness measurer. The regular Rockwell hardness tester penetrates too deeply.

In appearance much like the standard hardness tester, this new machine is adaptable to the measurement of the hardness of thin hard steel, as in the case of safety razor blades. Thin sheet metal such as rolled sheet metal, ferrous and non-ferrous, may also have its hardness measured by this tester.

The principle underlying the readings of the tester is the same as for the standard machine, *viz.*, an increment in depth due to an increment in load. The big difference is in the loading and in the sensitivity. The initial load is 3 kilograms and the major load may be 15, 30 or 45 kilograms, depending upon the thickness of the case hardening. To compensate for the loss of sensitivity caused by using a lighter load, a depth measuring system was devised more sensitive than the regular Rockwell. All in all, its sensitivity is on a par with that of the regular machine.

Whereas hardened tool steel is penetrated to a depth of about 0.0035″ on a regular Rockwell "C" scale test, the Superficial will, on metal of the same hardness and with the customary 30-kg. major load, penetrate to only

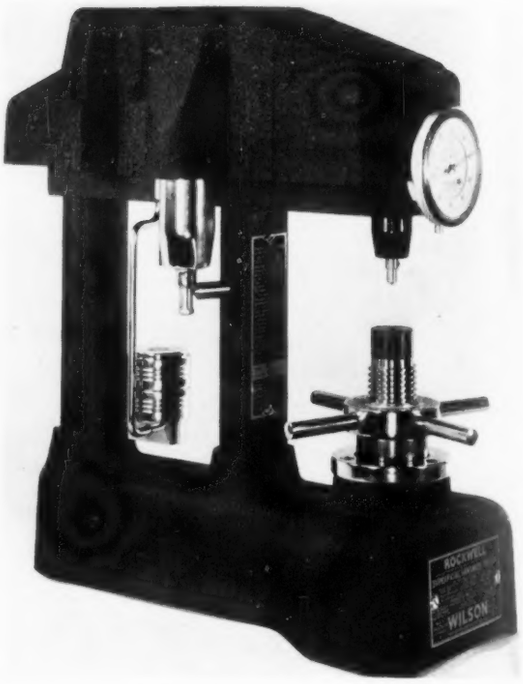
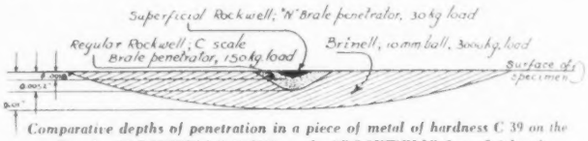
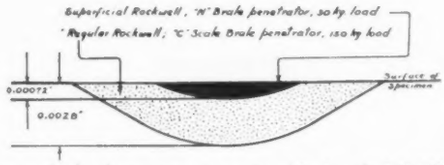


Fig. 123. The smallest model of the Rockwell superficial hardness tester.


Superficial Rockwell; "N" Brale penetrator, 30 kg load
Regular Rockwell; C scale Brale penetrator, 150 kg load
Brinell, 10 mm ball, 3000 kg load
Surface of specimen
0.0035"
0.004"

Comparative depths of penetration in a piece of metal of hardness C 39 on the Regular "ROCKWELL," 30-N60 on the "ROCKWELL" Superficial and 362 Brinell.


Superficial Rockwell, "N" Brale penetrator, 30 kg load
Regular Rockwell, "C" Scale Brale penetrator, 150 kg load
Surface of Specimen
0.0007"
0.0028"

Comparative depths of penetration in a piece of hard steel of "ROCKWELL" Hardness C65, as determined on the regular "ROCKWELL," and of hardness 30-N82 on the "ROCKWELL" Superficial.

Fig. 124. Relative depths of penetration made by the different penetrators of the Rockwell machines on the same specimen.

about 0.0010″ in depth. One point on the scale of hardness for any test made on one of these Superficial machines corresponds to differences in depth of penetration of only 0.001 mm. (approximately 0.00004″). Relative depths of penetration made by different indenters are shown in Fig. 124.

The regular 1/16″ diameter steel ball is used on the Superficial machine when measuring brass, bronze and unhardened steel. Because a smaller load is used and, therefore, a smaller penetration, the diamond cone indenter must be ground with the greatest of micrometric precision and with an angle of exactly 120° at the point in order to make these tests comparable with other Rockwell machines. Inasmuch as the measurements made on the Superficial machine are micrometric it is important that the surfaces to be tested be smoothly finished, but they need not be polished. Dust, scale and grit should be removed from the surface of the specimen under test.

Hardness Number Designation—Only one dial graduation is used on the superficial hardness tester. See Fig. 125. The designations for the hardness numbers thus ob-

tained differ somewhat from those of the regular machines. In using this special model one writes the value of the major load in kilograms first, then the letter N if the "Brale" N is used as a penetrator, or the letter T if the 1/16" ball is the penetrator, and finally, the dial reading. The scale pan alone furnishes a load of 15 kg. as a major load and each of the two extra weights add 15 kg. more so that the major load may be 15, 30 or 45 kg. If the scale reading is 50 for either one of the penetrators with a load of 15 kg., the hardness number may be 15-N-50 or 15-T-50.

The following are the established prefix symbols:

For N Brale		*1/16" ball*
15-N	with 15 kg. major load	15-T
30-N	" 30 " " "	30-T
45-N	" 45 " " "	45-T

It will be noted that the major loads are much smaller than for the regular Rockwell machine. By amplifying the depth measuring device, however, an equal sensitivity is maintained. In a general way, a hardness test is influenced by the hardness of the material tested to a depth at least 10 times the actual depth of indentation. The recent tendency to develop instruments with smaller major loads and more sensitive indicators, whether on an indentation instrument like the Superficial Rockwell or on a cut instrument like the Bierbaum Standard Instrument, appears to be a move in the right direction.

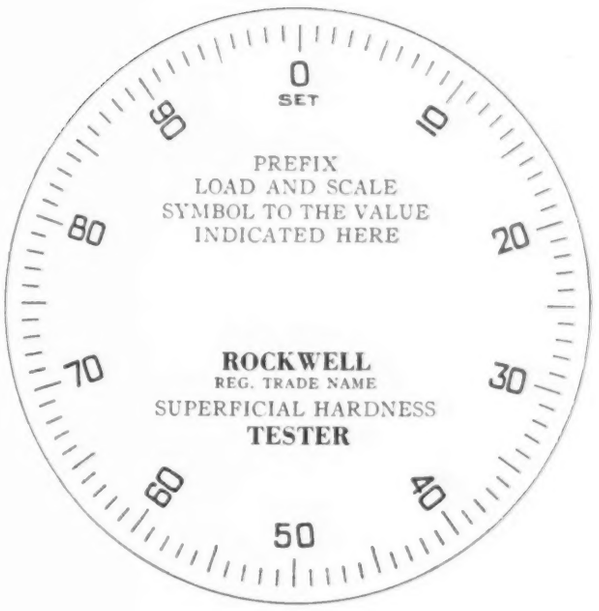


Fig. 125. Full-size reproduction of the dial of a Rockwell superficial hardness tester. The pointer revolves once for a 0.1-mm. (approximately 0.004") motion of the penetrator.

LETTER TO THE EDITOR

"Human Limitations of Measurement and Control"

To the Editor of *Instruments*

Measuring tools and controllers are made by men to help other men in their daily work. Measurements are made by men, the instruments are tools only to make these measurements. No measurement or control can be any better than the man who is making it.

You write, discuss and describe various new instruments in every issue of your magazine, seemingly forgetting or neglecting the most important part—the human part of all measurements and controls. The following has been written to remind you of the part that man plays in measuring and controlling with automatic controllers. In writing this, reference has been made to the literature of two instrument manufacturers. Their literature was used only because the writers happen to be in daily contact with their controllers.

In the few years that we have lived in this world we have found it to be a curiously individualistic word. Of all the things or actions that we have seen or known, no two are exactly alike. It is true that many things appear to be alike at first glance, as the proverbial two peas in a pod; but on closer visual examination these two peas are found to have individual markings and differences, and the micrometer or microscope will show variations in size and shape. It is also true that many things are sufficiently alike to be classified as rocks, trees, animals, or men. These classes, however, may be subdivided into smaller divisions such as dogs, cats or sheep; and the subdivision may go on until we arrive at a single entity which is an individual in a class of its own.

Our mind contacts the world outside of itself through our natural senses. Some phenomena, such as sound and light, impress our senses directly; others, such as radio waves, we can perceive only indirectly with the aid of instruments that make some of their effects impress our senses.

Our senses are messengers carrying impressions of the outside world to our minds. As human beings we are much alike but as individuals we differ distinctly from one another. The individual senses of different persons receive the impressions of natural phenomena in somewhat different ways and transmit this intelligence to their respective minds somewhat differently, with the result that we all see, hear, smell, taste and understand the world around us in our own individual way.

To understand and explain the world in which we live we have invented our sciences. All our "exact sciences" are based on measurements, that is to say on comparisons of entities or events among themselves and against "yardsticks" or units.

When it comes to things or actions, we soon find that our senses are inaccurate in distinguishing differences of lengths, weights, or time intervals. We also find that we have to establish purely arbitrary and abstract measuring units that have no physical existence. We have invented a system of measures based on measurement of length, mass and time. The primary standard of length is defined as

> . . . the distance between two lines at 0°C. on a platinum-iridium bar know as the International Prototype Meter deposited at the International Bureau of Weights and Measures. The International Prototype Meter is 1553164.13 times the wave-length of the red cadmium line in air at 760 mm. pressure and 15°C.

We are quoting this scientific sounding definition of our basic measure of length merely to point out just how detached, arbitrary, and non-existing our measuring units are. Our mind can conceive a definite exact unit of distance which we may call a meter or yard. Yet when our eyes or senses require a visible meter or yard the best we can do is to take a piece of metal, scratch two lines on it and call the distance between these two lines our standard. To us these two limiting lines on that particular platinum-iridium bar are the most interesting part of our Prototype Meter. Some years ago the International Committee of Weights and Measures started out in earnest to determine the width of these limiting lines in order to define the original Meter more accurately. The lines were found to be 0.006 to 0.008 mm. wide, not much wider than the length of some hydrocarbon molecules. The whole story is told in those 0.006-mm. to 0.008-mm. wide lines. With all the brains, instruments, time and (we presume) money at their disposal, the Committee could not report definitely that the lines were 0.0069, 0.0076 or any other definite number of millimeters wide. All they could do was to confine the width between 0.006 and 0.008 mm. And to the writers' understanding of measurements, that is all that we ever will be able to say definitely about any of our measurements. We will never be able to say that we are exactly right, but we can definitely say that we are not more than a mile, yard or inch off in our measurement. This is only part of the story of the Prototype Meter. Actually it has taken considerably more trouble and effort to confine that meter between those two lines.

Duplicating that original Meter introduces troubles and difficulties of its own. To suit any particular purpose we must make our meter or yardsticks of wood, metal or other suitable material. Knowing that we can never be sure of our duplicate

Continued on page 156

INSTRUMENTS' BOOK SHELF

Gases and Metals. By COLIN J. SMITHELLS. John Wiley & Sons, Inc., New York, 1937. Cloth, 5½ × 8¾ inches, viii + 218 pages. Price $4.50.

No better brief characterization of this recent discussion of gas-metal phenomena could be made than the author's own sub-title, "An Introduction to the Study of Gas-Metal Equilibria." It is printed in easily-read type, includes a subject and author index, frequent literature references, 145 figures, and numerous tables. Consideration of this format and the title makes it self-evident that the treatment cannot be exhaustive or all-inclusive. Nevertheless the author has covered remarkably well the wide range and variety of problems which are involved in gas-metal studies.

Smithells has been active in research in this field for a long time and has evidently been forced to recognize that the complexity of the situation makes the establishment of general theories difficult and dangerous. Nevertheless, this conservative attitude on his part detracts from the interest of the book. The reader who is conversant with some of the problems will feel that their treatment is inadequate and that the author has failed to bring to bear any new light which might have been expected from one who has attempted to rationalize a broad field. For instance, the numerous experiments and consequent theoretical developments which have resulted from work with heavy hydrogen have scarcely been mentioned. In describing the analysis of gases in metals by vacuum fusion, the studies of fractional oxygen in steels have been passed over entirely.

The close interdependence of phenomena of adsorption, diffusion, and solution is clearly established and these three topics provide the subdivisions of the book. In dealing with each topic the fundamental experimental methods used in its study are described and this is another praiseworthy feature of the book. An effort has been made to include as many different gas-metal systems as possible and the disproportionate amount of work which has been expended on the palladium-hydrogen problem has been skillfully minimized. By the same reasoning, one feels that the less numerous experiments with gases other than hydrogen might have been assigned a somewhat greater importance.

In brief, "Gases and Metals" is a helpful and readily understood introduction, but it should not be considered as a complete or advanced treatment of the subject.

—GERHARD DERGE, *Metals Research Laboratory, Carnegie Institute of Technology, Pittsburgh, Pa.* (8)-B-

A Survey Course in Physics. By CARL F. EYRING, Prentice-Hall, New York, 1936. Cloth, 6 × 9 inches, 378 pages. Price $3.00.

This book is another of the several recent attempts to make a division of science understandable to the non-science student. It is a well thought out attack on the difficult problem of making physics understandable to the student with no mathematical background. The material is almost entirely descriptive and the only mathematics used are the very simplest algebraic expressions. The examples drawn upon and the illustrations throughout the book are from every-day experiences. Many are drawn from the human body itself and from other common associations, such as the automobile and things in the home. The author has done surprisingly well in finding so many striking illustrations from common human surroundings and experiences. For example, he shows that the energy of a pound of fat worked off in exercise would be equivalent to lifting oneself through a distance of 10,000 ft. and follows with the admonition that ". . . A hint to the wise is sufficient. Balance your intake against your expenditure. It is the safest and surest way to attain a graceful figure."

The book contains chapters on the usual divisions of physics, including one introductory chapter, three on mechanics, three on heat, four on vibration and sound, three on light, color, and optical instruments, two on electricity, and one on atomic physics. The chapters on sound are particularly complete, including discussions of the structure and mechanism of the ear, the limits of audition and auditory sensation diagrams (after Fletcher), the loudness scale with a definition and explanation of the decibel and the physical basis of the musical scale. A chapter on musical instruments, speech and auditoriums, gives a brief analysis of the principal musical instruments including the human voice and a discussion of the accoustics and accoustical treatment of buildings.

The chapters on light and color are prepared with special reference to their use in art, although the fundamentals of interference, refraction, and dispersion are also covered.

The chapters on electricity have more of the usual examples and illustrations commonly seen in physics text books, such as batteries, charged condenser plates, galvanometers, etc., and for that reason probably would not have as great an appeal to the non-scientific student as will most of the rest of the book. A brief discussion of large electrical generating and distribution systems and something on the radio and electronics might well have been included, even if at the expense of the common treatment of static electricity and the door bell as a homely manifestation of electromagnetism.

On the whole, the book should fulfill the purpose for which it is designed, for it should give students in the arts an insight into the applications of physics to everyday life. It has the weakness which is almost inherent in any book of this type: that is, if it should awaken an interest in physics to the degree that a student would desire to take it up as a science, he would not be prepared to enter more advanced courses in physics, primarily because of the emphasis which the book places on the qualitative aspects of the science and the lack of development of the quantitative parts which can be done only through the application of mathematics.

—L. L. NETTLETON, *Gulf Research & Development Co. Laboratory, Harmarville, Pa.* (12.1)-B-

A Catalogue of the Epstean Collection on the History of Photography and Its Applications especially to the Graphic Arts. Columbia University Library, Columbia University Press, 1937, New York. Board, 6¼ × 9¾ inches, 110 pages. Price $1.50.

It is the main purpose of this catalogue to make the contents of the Epstean Collection known to the wide circle of students of photography and the graphic arts, and to libraries.

There is at present no comprehensive bibliography of the subject available in print, and this catalogue may very well serve as a key to the accumulated wealth of photographic literature. Mr. Epstean's collection of books, pamphlets, and periodicals on photography is one of the most comprehensive libraries of that subject in existence.

"Many years ago," writes Mr. Epstean in the Foreword, "I began collecting a library of scientific and applied photography. It was the need for a thorough theoretical understanding of the reproductive processes by photography, in which I have been engaged for some 45 years, which led me to bring together these books. Illustrations are today looked upon and accepted as a matter of course, and few realize how much study and work lie behind the present wealth and quality of photographic illustration. It was the heritage of books which led us along the paths of experimentation and new understanding." (12.4)-B-

QUESTIONS & ANSWERS

Instruments receives a constant stream of questions, and answers most of them immediately. Q&A's of general interest to most subscribers, and involving subjects which are not dealt with in readily-accessible sources, are printed occasionally in this Department.

Temperature Standards

Question No. 8 **Subject Index 2.06**

"I am interested in obtaining some information on temperature standards for calibrating or checking thermometers and thermocouple potentiometers between the ranges of 20°C. to 150°C. Any information that you can give me on methods and equipment will be highly appreciated."

A.—There are three categories of standards:

(1) Fixed-point apparatus. This category includes two classes: (*a*) the International Standard apparatus, method and formulas (for barometer correction, etc.) for the Ice Point and for the Steam Point; (*b*) motor-stirred baths for the transition points of sodium sulphate, etc. —media other than water and fixed points other than 0° and 100°C.

(2) Motor-stirred, well-insulated baths equipped with extremely accurate thermostats and precision short-range temperature indicators. Medium is generally some oil. This set-up is not a "standard" unless so certified and carefully maintained.

(3) Standard temperature-indicating instruments with Bureau of Standards certificates. This category includes mercury-in-glass thermometers, platinum-resistance thermometers and even some thermocouples. The thermometer certificates report the error at three or four points so that a correction curve can be drawn for the entire scale range; the resistance-bulb certificates similarly permit the preparation of a resistance curve whereby the use of a precision Wheatstone bridge (or, for a short range, of an unbalanced bridge) with the certified bulb can give temperature measurements to ±0.02°C.; the thermocouple certificates similarly give an emf. curve whereby the use of a precision potentiometer permits temperature measurements to ±0.02°C. NOTE. The Bureau of Standards certificate can't make a silk purse out of a sow's ear: it can't make a low-grade device better. If, for example, you decide to use a mercurial thermometer and purchase one on a price basis alone, its glass may undergo relatively large dimensional changes, so that in a few months this "drift" will have made the Bureau's calibration curve not only a superfluous luxury but a source of misplaced confidence in the thermometer. It should be realized that thermocouples are subject to contamination; also, if a Wheatstone bridge is used, care should be taken always to send the same amount of current through the instrument.

INSTRUMENTATION FORUM

PROBLEMS — SOLUTIONS — DISCUSSIONS

MARCH PROBLEM (No. 17). Consultants have not yet made their recommendations as we go to press. Solutions and discussions in next issue.

Problem No. 19 — Subject Index 2.06

MEASURING TEMPERATURES OF LIVING TISSUES

Biologists have to measure accurately the temperatures of different portions of a single animal's anatomy. One problem is the accurate measurement of temperature DIFFERENCES between outer and inner cell layers, often less than 0.001" apart, requiring thermocouples or resistance "bulbs" of almost microscopic dimensions, which can be inserted with least irritation and which the animals can "get used to." This may be an opportunity for practical instrument users to tell their scientific brothers how to do it. Five dollars will be paid for every solution (or critical discussion clearly pointing the way to a solution) which is accepted for publication. Address Instrumentation Forum, 1121 Wolfendale St., Pittsburgh, Pa. Type double-space, on one side of paper. Draw diagram in black ink on separate sheet. Mail before June 15. Solutions and discussions accepted will appear in July 1938 issue.

INSTRUMERRIMENT

Conducted by Felix Malone, Instrumirthologist

In this department we print each month (mebbe) SERIOUS versions of various subjects treated with too much humor elsewhere in this mag. "Gravity, not levity"—that's our masthead motto. "Solemnity, not jocosity"—that's our sober slogan.

InstruMerrimen Terminology

(Continued)

Hysteresis—**1.** Wife's behavior when hubby, after her reducing dinner, calmly puts on his hat and says he's going to Beefsteak Joe's. **2.** The study of preceding centuries' mistakes, so people can learn to make worse mistakes.
Combustion—To enter suddenly.
Baumé Degree—The way ointments are rated.
Angström Unit—Uneasy harem attendant.
Calorie—**1.** What reducing women cut down on. **2.** Where seats are cheapest.
Inverse Hyperbolic Cosecant—"Well, it's this way: when a carboy of acid leaks, the bookkeeper sends one of them things instead of a plain invoice." (Answer actually made by an apprentice.)
Dextrorotary—Hoop trick by stage magician.
Multiplier—**1.** Rabbit. **2.** Slum rat on dole.
Kilowatthour—To idle from 2 to 3 a.m.
Diametral Pitch—The old bean ball, outlawed in major leagues.
Ignition—A lock where you push in a key to start a car.
Foot-pound—**1.** Patrolman's gait. **2.** Tap dancing.
Deliquescent—Criminal.
Circular Mil—Round jailhouse.
Mean Candle-power—Mae West's gaze out of the corner of her eyes.
Rhomble—Like a Cuban dancer.
Isotropic—"G'wan, you can't fool me: how can a hot climate be icy?"
Factorial—Pertaining to where we work.
Integral—What Andy and the Kingfish are always boasting they have.
Quantic—Where Marines train.
Adiabatic—A guy that can't eat sugar.
Triclinic—Where this guy is first examined.
Yield Point—When she starts murmuring "don't" instead of wordlessly slapping you.

Novel Shoe Testing Instruments Shown In England

ACCORDING to published reports, the Boot Trade Research Association has, during the past twelve months, made considerable advances in studying the effect of gait and foot pressures on shoe wear through motion picture examples and through the use of specially designed apparatus designed to indicate wearing trends.

One of these is the Gait Recorder which produces an accurate record of the movement of the foot in regard to pressure on a chemically prepared paper run through an electrical apparatus. This paper is marked according to contact with certain points on the walker's shoe with an electrically connected plate laid on the floor. Walking over the plate produces a line for each contact showing the progress of the walk and its approximation of a "standard" gait. From the record made, it is stated that it is possible to build up the shoe form to correspond with peculiarities in gait and compensate for them.

An allied piece of apparatus is the Electrograph, a device for recording foot pressure and detecting abnormal pressures. The subject stands on a small square plate bearing on a tin plate and one of aluminum; a sheet of paper inserted between the metal plates is impressed with the outline of the foot when an electrical current is passed through the metal plates; the image secured from this apparatus is darkest where pressure is heaviest, giving a record of any unusual pressure condition.

Another device is an electrically driven treadmill supported on a slightly raised stand; this is devised to enable motion picture records to be made of the leg and foot action of a person walking on the treadmill when the normal walking movements are simulated at various speeds in accordance with the speed at which the endless belt of the machine is driven.

These several machines are being exhibited at the current Shoe and Leather Fair in London.

—Report from OSBORN S. WATSON, Trade Commissioner, London office, Specialties Division, Bureau of Foreign & Domestic Commerce, Department of Commerce.

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PERKIN, ELMER & MOFFITT
90 BROAD STREET, NEW YORK

Continued from page 153

measure-stick being exactly as long as the original, we must decide at some particular stage of comparison its length to be "close enough" to the original and let it go at that. So must the user of the duplicate meter make his decision on how close is close enough.

This deciding of "how close is close enough" is perhaps the most important human part of all our measurements and controls. We measure the quantities or actions of nature with a certain purpose. The requirements of that purpose determine the needed accuracy or limits of our measurement in each individual case. A housewife will not worry if the delivery man drops a piece of coal in the street when he is delivering a ton of coal to her cellar; on the other hand a chemist may spend considerable time and effort in determining the "exact" weight of the coal sample for his analysis.

Assuming that we have a measurement stick which has been compared to our satisfaction with the original Prototype, we have to find methods of comparing that measuring stick with whatever length we want to measure. For this purpose we have a wide choice of tools and instruments. A wooden yardstick and visual comparison will give us error limits perhaps of one percent; a vernier caliper shows differences of 0.001"; an optical comparator is designed to distinguish a millionth of an inch, while an interferometer assures accuracies of one part in several million; therefore the choice of a proper "stick" or instrument for each particular measurement is another important human part of our measurements.

When we come to communicating our individual observations of nature, the results of our measurements and the interpretations of our measurements and observations to each other, we encounter—beside peculiarities of individuals and individual minds—the peculiarities of words in languages. English is particularly notable for attaching several different meanings to the same word. A "dog" according to our dictionary means:

> A domesticated carnivorous animal belonging to the genus Canis, also name of various mechanical contrivances.

This habit of attaching double or triple meanings to words does not help us to understand one another. It is no wonder that we have misunderstandings in this world of individual things and happenings which we attempt to sense, measure and understand with our limited senses and imperfect measuring tools. The real wonder is that in this maze of approximations our collective minds have succeeded in finding many common denominators by which we have been able to formulate many scientific laws and theories which are at least approximately correct. Even with our imperfect means of transmitting this intelligence to one another we have been able to make considerable progress in understanding and directing or controlling many of the natural forces according to our desires.

Automatic controllers such as we have in mind in this discussion deal with rather complex conditions of liquid and gas pressures, temperatures, and rates of flow in various industrial or domestic applications. In controlling the multitude of individual conditions with the help of various forms of individual controllers, it becomes difficult to find the main underlying principles and so-called natural laws governing these happenings.

To what extent individuality and individual understanding enter here into discussion is best illustrated by a few examples from the literature of controller manufacturers. The very word "control" seems to cover a multitude of things just as the word "dog" which covers a multitude of various four-legged animals from St. Bernards to Chows of various sizes, shapes and colors as well as the various mechanical contrivances.

Apparently to avoid confusion, controller manufacturers have defined or explained the meaning of the word "Control." One manufacturer[1] says under the title "Definition of Control":

> The expression "Controlled Valve" is descriptive of a valve capable of controlling flow. Webster's International Dictionary defines "control" in part as follows: "To check or regulate expenditures; to exercise restraining or directing influence; to dominate or regulate; to hold from action; to curb, subject, and overpower." In every sense of the word there is a meaning of retardation or restriction which gives to the controlled valve a function directly opposite to that desired of any other fitting or equipment placed in the line of flow. Therefore, it is logical to consider that controlled valves *restrict* flow and at the same time pass *only* the required quantity.

We heartily agree with the reference to the Webster's International Dictionary as it helps us to keep to the beaten path. However, we find that control means a lot more beside controlling pressures, temperatures, etc. Before going any farther we should agree that in this discussion we are definitely limited to discussion of various mechanical devices used in controlling pressures, temperatures, and similar conditions of nature. Webster's "checking or regulating expenditures" does not apply directly to those controllers except in a round-about way. Any controller of course is bought and used to check or regulate expenditure as it is supposed and expected to produce a more uniform product more effectively and cheaply. Somehow this lengthy definition of "control" leaves us unsatisfied as to its meaning. The definition of "control" does not state shortly and definitely just what the writer means by the word "control."

On the pages of another manufacturer's catalogue[2] we find:

> To control is to maintain a constant invariable condition in a system.

This is just how we like our definitions—short and snappy. However we cannot admit that this is the correct definition of "control" unless the words "constant" and "invariable" also have two or three meanings as the word "dog." We also believe it to be somewhat misleading. We, instrument builders and users, know that all automatic controllers are primarily actuated by variations of the controlled condition. The action of "on-and-off" control, such as an air-pressure controller in an auto service station, demonstrates this variation in unquestionable terms. In the case of throttling control the variations are not as obvious and thereby hangs the tale. We must not forget that above us in high places such as Head Offices, Banks, and other Holy of Holiest are Master Minds—Captains of Industry—controlling us—you and me—very much in the same way as we try to control our variables. We suspect that these masters are humans, the same as you and me. It so happens that every once in a while in their inspection tours they come across a poor galley slave whose only object in life seems to be to keep conditions in a system, or several systems, more or less constant and invariable. Very often these conditions just simply refuse to act anywhere near like invariable, resulting in charts painted red, blue, and green in all kinds of fancy curves. The whys and wherefores of thereofs are sometimes very hard to explain, particularly if one of these Master Minds has the individual inclination to be literal-minded and has read the instrument manufacturer's statement promising to keep "constant invariable condition within a system."

"Why in the name of this and that cannot these high-priced instruments and highly-paid instrument men (so they say) do what they are supposed to do?"

So in all fairness to those galley slaves, builders and users of our instruments and controllers, let us modify our word definition of "control" somewhat and say:

> To control is to keep a condition in a system within definite predetermined limits.

It is the opinion of the writers, individualistic of course, that this definition of control describes the actuality reasonably close and at the same time gives us an excuse for not always reaching absolute invariability in our controls.

There are several other measurement and control terms which we should like to discuss and redefine to suit our own individual understanding. However, we realize that we cannot hope to remake the world, at least not in one letter to the editor, so we decide to leave you and your readers in ignorance of the true meaning of other terms . . . for a time!

We started out to say that humans and limitations are indivisibly tied up with our measurements and controls. We have gone to some length to show that the basic conception of the idea of "control" can be and is understood and described differently even by the people who are intimately connected with manufacture and use of controllers. As we said in the beginning, controllers are made by men to help other men do their work more effectively or more accurately. Limitations of men as well as machinery reflect themselves in the final result. Calling a controller "automatic" does not do away with the human element of any control. The controlman is and always will be the most important part of any control. He is the one that makes the controller to control, he is the one to decide "how close is close enough" and he is the one to ask for controllers capable of reaching that limit of closeness.

With the increase of precision in the controllers the task of choosing proper controllers for any particular job becomes increasingly more difficult. It would not do to buy a micrometer when a wooden yardstick will do the job. It should also be remembered that most of us are capable of using a wooden yardstick or steel tape more or less effectively, while the use of optical comparator or interferometer requires special skill and knowledge of the instruments. If the job at hand requires a high degree of accuracy, by all means buy the proper machines and above all do not forget the most important part of your instruments and controllers—the man who operates them.

P. J. Tobi
Instrument man
Wilshire Oil Co., Norwalk, Calif.

Robert Tobi
Mason-Neilan Regulator Co.
Los Angeles, Calif.

April 9, 1938

[1]Bulletin No. 167, V-Port Controlled Valves. The Foxboro Company, Foxboro, Mass.

[2]Instructions No. 2345, Air Operated-Compensated Precision-Type Controllers. Mason-Neilan Regulator Co., Boston, Mass.